The Early 21st Century Copper Boom and HIV/AIDS in Zambia *

Nicholas Wilson

Department of Economics, Williams College, Williamstown, MA 01267, United States†

First draft: July 2010

Current draft: September 2010

Abstract

Copper mining is one of the largest economic activities in Zambia, comprising close to ten percent of GDP. Between 2003 and 2008, the price of copper increased by over 400 percent. In response, copper production in Zambia increased by 70 percent and employment in copper mining increased by nearly 200 percent. This paper examines the effect of this economic shock on sexual behavior and the spread of HIV/AIDS in Zambia. I use nationally representative survey data on sexual behavior before and during the copper boom in conjunction with detailed spatial data on the location of survey respondents and copper mines. The results indicate that the copper boom reduced transactional sex, multiple partnerships, alcohol use at sex, coital frequency, pregnancy rates, and marital rates in the copper mining cities. These effects were concentrated among young adults and selective in-migration to the copper mining cities appears to have contributed to the reduction in sexual activity.

JEL classification: I18, J10, O12

Keywords: commodity shocks, copper mining, HIV/AIDS, Zambia

---

*I would like to thank Andrew Foster, Bill Gentry, Sara Lalumia, Peter Pedroni, Michael Rolleigh, Stephen Sheppard, Lara Shore-Sheppard, Anand Swamy, and Tara Watson for many helpful comments. In addition, this research would not be possible without the assistance of Alfred Phiri at the Zambia Ministry of Mines and Minerals Development. Zhaoning Wang and Wentao Xiong provided superb research assistance. All errors are my own. The findings, interpretations, and conclusions expressed in this paper are those of the author and do not necessarily represent the views of the aforementioned individuals or their employers.

†Tel.: +1 413 597 4868 Fax: +1 413 597 4045 E-mail: nlw3@williams.edu

1 Introduction

Copper mining is one of the largest economic activities in Zambia, comprising close to 10 percent of GDP (USAID 2006). During the global economic expansion of the mid-2000s, demand for copper increased dramatically. As a result, the world copper price increased by over 400 percent between 2003 and 2008. In response to the large increase in the world copper price, copper production in Zambia boomed. Between 2003 and 2008, copper output in Zambia increased by 70 percent, employment in copper mining increased by 180 percent, and real GDP per capita increased by 76 percent (between 2003 and 2007).

This paper examines the effect of the copper boom on sexual behavior and the spread of HIV/AIDS in Zambia. In doing so, it provides some of the first causal evidence on a growing policy debate: the effect of economic growth on the HIV/AIDS pandemic. Some in this debate (e.g., Fenton 2004) argue that poverty reduction is an important component in the fight against HIV/AIDS. Others emphasize that there is a positive gradient in the relationship between wealth and HIV prevalence, both within countries (Mishra et al 2007) and across countries in Sub-Saharan (Parkhurst 2010).

Although there is little reliable evidence of the causal effect of large economic shocks or economic growth on the HIV/AIDS pandemic, several studies have examined the effect of individual- and household-level economic shocks on sexual behavior. Dinkelman et al (2007) find in a panel of young adults in Cape Town, South Africa that negative household-level economic shocks (e.g., death or job loss) increase the likelihood of women engaging in transactional sex. Robinson and Yeh (2010) find that among a sample of 192 commercial sex workers in Busia District, Kenya individual- and household-level negative health shocks increase willingness to supply particularly risky transactional sex. Other studies which examine compensating differentials in sex markets, such as Gertler et al (2005), find that unprotected sex is associated with a price premium in the transactional sex market, suggesting that rising incomes among consumers of transactional sex may lead to increased risky sexual behavior.

As partly indicated by these studies, it is unclear whether economic growth will help alleviate the HIV/AIDS pandemic or exacerbate it. Rising wages and incomes, as well as associated socioeconomic and cultural changes, affect both the demand for and supply of sex. Increased employment opportunities for women outside of the transactional sex market should lead to a decrease in the supply of risky sex. Conversely, rising incomes among men may lead to an increase in demand for sex. Income and substitution effects from increased labor demand may affect fertility decisions and marriage, which in turn affect sexual behavior. Other literature, such as Lurie et al (2003) and Oster (2009a), discusses the role of migration in the spread of HIV/AIDS, and development and economic growth affect migration. Oster (2009b) argues that higher income may increase the behavioral response to increased HIV risk. Individuals with higher incomes face a higher price of risky behavior because of the greater forgone utility in expectation from increased risk of death. Although this suggests that economic growth will reduce risky sexual behavior, the causal evidence on this issue remains scant.

I use the sharp increase in output per capita in Zambia associated with the copper boom during this six year period to provide evidence on the general equilibrium effects of a large economic shock on sexual activity and the spread of HIV/AIDS. Examining the effects of commodity-led growth on the behavioral components of the HIV/AIDS pandemic may be particularly relevant given the importance of commodity-led growth in recent history in Sub-Saharan Africa (Beny and Cook 2009). However, as I discuss in more depth later in the analysis, copper production in Zambia differs from commodity production in many other settings in Sub-Saharan Africa so we should use caution in generalizing these findings.

My main empirical strategy is to use a difference-in-differences approach to exploit temporal and spatial variation in the intensity of the copper shock. I use detailed geographic information on the location of individuals and copper mines to measure how changes in sexual behavior associated with increases in copper production vary by distance to the mines. Data on sexual behavior come from repeated nationally representative cross-sectional household surveys, the Demographic Health Surveys (DHS) and the Zambia Sexual Behavior Surveys (ZSBS), conducted before and during the copper boom.

Several facts emerge from this analysis. First, the copper boom caused relatively large reductions in sexual activity, including particularly risky behaviors such as transactional sex and multiple partnerships. Second, these effects were concentrated within the urban areas surrounding the mines. Third, the spatial pattern of changes in consumer durable ownership and migration status are consistent with the interpretation that the effects of the copper shock were very localized. Fourth, younger individuals and unmarried individuals, the individuals who engage in the riskiest sexual behaviors, demonstrated the greatest reductions in sexual activity. Fifth, the copper boom not only reduced sexual activity for non-migrants living in the mining cities but also induced beneficial selection of less-risky individuals through in-migration.

These results offer useful insights for understanding the effect of large economic shocks and economic growth on the HIV/AIDS pandemic in Sub-Saharan Africa. This paper provides evidence suggesting that economic growth affects the HIV/AIDS pandemic. Existing studies of the relationship between economic growth and HIV/AIDS focus on the effect of HIV/AIDS on economic growth (Young 2005) or its determinants (Fortson 2009, Fortson 2010, Juhn et al 2009). I find that a large shock to aggregate production reduces risky sexual behavior. This suggests that the supply-side effects of rising incomes and economic opportunities for women outside of sexual activity dominate demand-side effects among men of rising incomes and increased willingness-to-pay for sex. However, in some sense, this may not be particularly surprising. The labor supply decisions of women at risk of entering the transactional sex market are probably quite responsive to increases in outside opportunities; transactional sex is likely a last resort. In contrast, many men, both low-income and higher income, report engaging in transactional sex.

The paper proceeds as follows. Section 2 provides the institutional context for copper mining in Zambia. Section 3 describes the copper boom. Section 4 outlines a conceptual framework for interpreting the empirical results. Section 5 discusses the data on sexual behavior, consumer durable ownership, and migration. Section 6 presents the empirical strategy. Section 7 presents the results. Section 8 concludes.

2 Copper Mining in Zambia

Copper mining is one of the largest economic activities in Zambia. It comprises approximately 10 percent of GDP (USAID 2006) and more than 60 percent of exports (United Nations Statistics Division 2009). The majority of copper ore mined in Zambia is smelted locally before being exported to foreign markets (Fraser and Lungu 2007). Copper and copper ore are transported by truck and rail to the south through Lusaka and on to South Africa and to the northeast through Kasama and Mpika to Tanzania.

Large-scale mining constitutes 90 to 95 percent of copper mining in Zambia.[1] During the period examined in this analysis, there were eleven large-scale mines located in nine mining cities in northern Zambia. Figure 1 shows the spatial distribution of the mines, as well as the main transportation networks in Zambia and several of the larger non-mining cities. Eight of the mining cities are clustered together in Copperbelt Province and the other mining city, Solwezi, is in an adjacent province, Northwestern Province. Without exception, each mine is located within 10 kilometers of the approximate centroid of the nearest city and in many cases the mine is located virtually in the center of the city. As shown in Table 1, eight of these cities are among the twenty largest urban areas in Zambia.

[1] Personal communication with Alfred Phiri, Mining Economist, Zambia Ministry of Mines and Minerals Development.

The ninth mining city, Chambishi, has a population of roughly 15,000.[2]

For much of the post-colonial era, the Zambian government owned the large-scale mines. Beginning around 2000, the government privatized copper mining and all of the large-scale mines were under the control of private ownership by the end of 2004 (Fraser and Lungu 2007). The new majority owners of the mines and the associated capital inputs are British, Canadian, Chinese, Indian, South African, and Swiss companies. The government of Zambia remains a minority shareholder in two of the copper mining operations in Zambia.

Copper mining is less labor intensive than agriculture in Zambia and represents a smaller share of employment than of GDP. According to the 2005 Labor Force Survey (LFS), the "mining and quarrying" industry employed 56,227 workers, or approximately one percent of individuals aged 15 years and older. However, in Copperbelt Province, where ten of the eleven aforementioned large-scale mines are located, 8.9 percent of employment is in mining and quarrying. Not only are ten of the eleven aforementioned large-scale mines located in Copperbelt Province, but eighty-two percent of employees in mining and quarrying reside in Copperbelt Province.

The LFS indicates that workers in the mining and quarrying industry are highly skilled and highly paid relative to other workers in Zambia. Forty-five percent of workers employed in mining and quarrying have completed between grade 10 and grade 12, four percent of workers have completed A level, and seventeen percent of workers have a degree. Only two industries in Zambia are more highly skilled: "finance, insurance, and real estate" (40,666 workers) and "electricity, gas, and water" (17,122 workers). Average earnings among mining and quarrying employees are approximately 986,000 kwacha (or roughly US$200) per month, again behind only "finance, insurance, and real estate" (1.22 million kwacha) and "electricity, gas, and water" (1 million kwacha).

The LFS also shows that mining employees are predominately older males who work full-time. Mining and quarrying has the greatest proportion of full-time workers of any industry and these employees work 56 hours a week on average. Ninety-three percent of mining and quarrying employees are male and the majority of females employed in mining and quarrying are part-time workers. Workers in the mining and quarrying industry are older than in any other industry. For example, 20 percent of workers are aged 40-44.

[2]The high population densities around the Zambian copper mines make this context different from many other mining settings. For example, Stuckler et al (2010) describe a setting where most of the population near mines are mine workers who reside in all-male hostels and many of the local female residents are sex workers who locate near the mines because of the large concentration of men.

3 The Copper Boom

As shown in Figure 2, in early-to-mid-2003 the world copper price began to increase dramatically after twenty-five years of relative stability.[3] By the time it reached its peak in April of 2008, it had increased by 428 percent. This increase was much larger than the two price shocks of the late-1980s and the mid-1990s, the largest of which was a 175 percent increase ending in February of 1989.

The large increase in the world copper price was an exogenous shock to Zambian copper production. Although copper is one of its largest economic activities and Zambia was the 8th largest producer of copper in the world in 2006, Zambia produces a small share of the world's copper supply. For example, Zambia produced nearly 515,000 metric tons of copper ore in 2006, which constituted 3.4 percent of the total world output of more than 15 million metric tons. In contrast, total copper output in Chile, the world's largest copper producer, equaled 5,361,000 metric tons in 2006 (International Copper Study Group 2010).[4] The most recent copper cartel, the Intergovernmental Council of Copper Exporting Countries (CIPEC), was founded in 1967 (Panayotou 1979). Indeed Zambia was a founding member, but the cartel ended in 1988, consistent with the finding (Pindyck 1978) that copper cartelization yields only minor benefits to cartel members because of the responsiveness of secondary (i.e., scrap) copper supply.

In response to the copper price shock, copper production in Zambia boomed. Figure 3 shows annual copper production in copper mining from 2000-2008. After reaching approximately 335,000 metric tons in 2002, the year prior to the price shock, annual copper production increased by 70 percent to more than 569,000 metric tones by 2008. Excluding two mines with declining output (i.e., Bwana Makuba and Nchanga mines) from this analysis makes the increase in copper production even more pronounced. Although large-scale copper mining is quite capital intensive, employment in copper mining also increased dramatically over this period. Figure 4 shows annual employment in copper mining from 1999-2008. Employment in copper mining increased by over 180 percent during the copper

[3]This figure reports the monthly world copper price and annual real GDP per capita in constant 2005 US$. Copper price data come from the International Monetary Fund (IMF) database. The copper price series in this database is the London Metal Exchange (LME) spot price for grade A cathode at European ports. Real GDP per capita data (in constant prices) come from, "Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 6.3, Center for International Comparisons of Production, Income, and Prices at the University of Pennsylvannia, August 2009."

[4]The other countries that produce more copper than does Zambia are the United States (1,220,000 metric tons), Peru (1,049,000 metric tons), Australia (859,000 metric tons), China (844,000 metric tons), Indonesia 9816,000 metric tons), and the Russian Federation (675,000 metric tons).

boom. The copper boom had large effects on aggregate output in Zambia. As shown in a previous figure (i.e., Figure 2), the increase in copper production was associated with a large increase in GDP per capita: between 2003 and 2007, GDP per capita grew by 76 percent.

Although total copper production in Zambia increased dramatically, two of the mines experienced large declines in production during this period because they began to run out of copper.[5] After production increased from fewer than 10,000 metric tons in 2002 to over 50,000 metric tons in 2006, copper output in Bwana Makuba mine in Ndola fell to roughly 25,000 metric tons in 2007. Production in Nchanga mine in Chingola fell relatively steadily from nearly 180,000 metric tons in 2002 to slightly more than 70,000 metric tons in 2008. In contrast, production at eight of the other nine mines increased and production at Konkola mine in Chililabombwe remained relatively flat.

4 Conceptual Framework

There are several reasons to think that the copper boom raised incomes in mining areas and affected sexual behavior in these areas as well. An exogenous increase in the price of copper should have increased demand for labor among mining firms. Thus, the immediate effects of an increase in the world copper price likely were an increase in equilibrium employment in copper mining and an increase in the equilibrium wage. If the supply of mining labor is inelastic, then much of the benefit of an increase in demand for mining labor accrued to existing mining employees. However, Figure 4 indicates that the benefits of the copper boom were enjoyed by new mining employees as well, as employment in copper mining nearly tripled. In addition, spill-over effects from increased copper production (e.g., increased demand for auxiliary services) mean that the copper boom likely raised the standard of living among individuals not employed in mining.

These changes in income and relative prices would have affected behavior in several markets related to sexual activity. Changes in income and labor supply should have affected the dating and marriage markets. For example, if richer men are more highly valued in these markets, then we might observe an increase in dating and/or marriage among the male beneficiaries of the copper boom. A slightly different line of reasoning suggests that we might observe a substitution toward dating and away from marriage. Magruder's (2010) model of marital shopping predicts that an increase in life expectancy might increase the

[5] Personal communication with Alfred Phiri, Mining Economist, Zambia Ministry of Mines and Minerals Development.

marital search period and reduce the rate of new marital formations.

The copper boom would have also affected the transactional sex market. Edlund and Korn (2002) argue that women in transactional sex markets earn a compensating differential for the associated social stigma in the marriage market. As the financial prospects associated with women's marital opportunities improve with the copper boom, one would expect a decreased willingness to supply transactional sex. Similarly, Robinson and Yeh (2010) show that negative economic shocks among commercial sex workers increase their willingness to supply particularly risky sex because of the desire to smooth consumption. Thus, rising incomes may have reduced willingness to supply risky sex on the extensive margin as well as the intensive margin. On the other hand, rising incomes may increase demand for transactional sex if transactional sex is a normal good.

There are several other possible effects of the copper boom. First, in Oster's (2009b) model of demand for risky behavior, rising incomes increase the continuation value of life, increasing the expected marginal cost of risky sex and reducing the equilibrium quantity of risky sex. Second, in a labor supply model where individuals choose effort to allocate to various tasks, an increase in copper mining employment and wages may be associated with increased effort exerted in the formal labor market and decreased effort exerted in marital search and sexual activity. Third, the increase in economic opportunities in mining areas may have induced labor migration to the mining areas. Increased in-migration likely affects the supply of sexual activity and demand for sexual activity.

5 Data and Descriptive Statistics

The individual- and household-level data for this analysis come from two sets of repeated cross-sectional nationally representative household surveys: the Demographic Health Surveys (DHS) and the Zambia Sexual Behavior Surveys (ZSBS). I use the 2001 and 2007 survey rounds of the DHS and the 2003 and 2005 survey rounds of the ZSBS. These data include information on sexual behavior, consumer durable ownership, and migration status. In addition, I use administrative records on the location of the primary sampling units used in these surveys to calculate relatively precise measures of the location of each survey household. This process yields 3,670 individuals in the 2001 DHS, 4,150 individuals in the 2003 ZSBS, 3,746 individuals in the 2005 ZBS, and 13,646 individuals in the 2007 DHS.[6]

[6]The 2001 DHS oversamples females by sampling only females in some households. I exclude these female-only oversampled households from the analysis to avoid complications associated with creating ad hoc sample weights.

These surveys capture several dimensions of sexual behavior. In addition to standard demographic questions about marital status and pregnancy, the surveys ask respondents to enumerate up to their last three sexual partners in the twelve months prior to the survey date. I use these partner histories to construct indicator variables for whether the respondent had any sexual partner in the past twelve months and whether the respondent had multiple partners in the past twelve months. All of the surveys ask the respondent whether they used a condom the last time they had sex with a given partner in the past twelve months and I use this information to construct a measure of the proportion of sex acts that were unprotected conditional on reporting a sexual encounter in the past twelve months. The ZSBS asks all respondents whether they exchanged sex for money (or money for sex) in the past twelve months and the DHS asks male respondents this same question. I use this information to construct an indicator variable for transactional sex. The surveys ask respondents when was the last time they had sex and I construct an indicator variable for whether they had sex in the past month. Finally, as an additional measure of risky sexual behavior the surveys ask respondents whether they consumed alcohol before they had sex.

Table 2 shows the gender-specific age profiles for each of these measures of sexual behavior. For this analysis, I focus on describing some basic facts about gender and age differences in sexual behavior so I pool all four of the survey rounds to calculate sample means. Column (1) shows the proportion of individuals in each gender-age demographic group who were currently married at the time of the survey. Several facts emerge from this analysis. First, females marry earlier than males. For example, 20 percent of females age 15-19 are married whereas only 1 percent of males in this age group are married. Similarly, 65 percent of females are married by their early twenties whereas only 28 percent of males age 20-24 are married. Second, marital rates fall at older ages among females yet stay constant among males. Among females, marital rates begin to fall around age 40-44 and only 72 percent of females age 45-49 are married. In contrast, marital rates among older males stay near 90 percent through age 55-59.

Column (2) shows the proportion of individuals in each demographic group who report having any sexual partner in the twelve months prior to the survey date. Although only 1 percent of males age 15-19 are married, 32 percent report having a sexual partner in the past twelve months. Similarly, more females report having a sexual partner in the past twelve months, 42 percent, than report being married. Thus, although marriage is the norm and the majority individuals are married by their twenties, pre-marital sex is a substantial part of sexual activity.[7]

For two of the riskier sexual behaviors, multiple sexual partners and transactional sex, there are large differences by gender in average self-reported sexual activity. Many male respondents report having multiple sexual partners in the twelve months prior to the survey date. As shown in Column (3), nearly 6 percent of males age 15-19 report multiple partnerships. This figure jumps to over 15 percent for age 20-24 and peaks at slightly more than 20 percent for age 25-29. Although this figure slowly declines for age groups above 25-29, more than 11 percent of males in the oldest age group (i.e., age 55-59) still report multiple sexual partners. In contrast, only 2.1 percent of females age 15-19 report multiple partners and this figure declines with age. The pattern of transactional sex by demographic group is similar to that for multiple partnerships. As shown in Column (4), 6.6 percent of males age 15-19 report paying money for sex. This figure peaks at 9.6 percent for age 20-24 and slowly declines for age groups above 20-24. In contrast, 5.2 percent of females age 15-19 report exchanging sex for money and this figure figure declines with age. Gender differences in mis-reporting may explain these differences in average self-reported behavior. Gersovitz et al (1998) show that females under-reporting sexual activity and/or males over-reporting sexual activity is more likely to explain these gender differences in sexual behavior than is the existence of a small group of high sexual frequency women not captured by the survey.

The demographic pattern for alcohol consumption before sex is similar to that for marital rates or having any partner. At younger ages, females are more likely than males to report alcohol consumption before sex. By the middle of the age distribution, these differences disappear and among older age groups males report higher rates of alcohol consumption before sex than do females.

Among younger age groups females are more likely than males to report having had sex in the past month, but males quickly reverse this gender difference. For example, 44 percent of females age 15-19 report having had sex in the past month, whereas only 31 percent of males in this age group report doing so. However, by age 25-29 males are slightly more likely to report having had sex in the past month and this figure continues to increase with age for males through age 45-49 and declines slowly with age for females.

There is a large difference in condom use by gender, but in this case it is females who are more likely to report engaging in the riskier behavior. As shown in Column (6), more than 88 percent of measured sex acts reported by females were unprotected. Slightly less

[7] Forty-six percent of unmarried males and thirty-seven percent of unmarried females report having a sexual partner in the past twelve months. Over 98 percent of married males and over 97 percent of married females report having a sexual partner in the past twelve months.

then 80 percent of measured sex acts reported by males were conducted without a condom. Differences between condom use inside of marriage and outside of marriage may partly explain this difference. The likelihood of unprotected sex increases with age, largely as does the prevalence of marriage. Because women marry early than men and the Zambian population is relatively young (e.g., the average age in this sample, which is conditional on being at least age 15, is 29 years old), females may be more likely on average to have unprotected sex than are men.

Rates of childbearing are relatively high in Zambia and 32 percent of females report being pregnant in the twelve months prior to the survey. This number seems slightly high compared to the estimated total fertility rate in Zambia, 5.91 (Fortson 2009), suggesting that respondents interpret the "twelve months" prior to the survey as a period longer than twelve months. Column (8) shows pregnancy rates by age of the respondent. Pregnancy rates are high even at young ages (e.g., 20 percent for age 15-19), peak among women ages 20-24 and 25-29, and decline to only 4 percent among females age 45-59.

Because my main empirical strategy relies on comparing the change in sexual behavior in mining cities to the change in sexual behavior elsewhere, it is useful to examine possible differences between these areas. Table 3 displays basic development indicators, demographic characteristics, and measures of sexual behavior in the copper mining cities, in the rest of Zambia, and in districts on the copper transportation routes.[8] I define a mining city as the circle with a 10km radius located at the approximate centroid of the urbanized area. This implementation captures all of the urban area (i.e., area contiguously populated with structures) visible on satellite imagery for each of the nine copper mining cities in Zambia.

As shown in the first columns in Table 3, residents of mining cities enjoy a higher standard of living than does the rest of Zambia. Households in mining cities are about twice as likely to have a high quality floor (73 versus 34 percent), a refrigerator (28 versus 11 percent), a television (49 versus 21 percent), or a car (5 versus 3 percent) than are households in the rest of Zambia. Motorcycles are extremely rare in Zambia, with less than 1 percent of households reporting owning a motorcycle. Perhaps surprisingly, household bicycle ownership is higher in the rest of Zambia (41 percent) than in mining areas (27 percent).

Rural-to-urban migration in Zambia means that residents of mining cities are more

[8] There are 72 districts in Zambia and the copper transportation routes pass through 19 of these districts. The districts on the copper transportation routes are: Chibombo, Chinsola, Choma, Isoka, Kabwe, Kafue, Kalomo, Kapiri Mposhi, Kasama, Kazungula, Livingstone, Lusaka, Masaiti, Mazabuka, Mkushi, Monze, Mpika, Nakonde, and Sernje.

likely to be migrants (22 percent) than are residents of the rest of Zambia (17 percent). Interpreting the level of these figures requires caution because the measure of migration is based on whether the individual has lived in the same household location for at least a year or not. Thus, this measure defines anyone who has relocated within a given city or village as a migrant even if they lived in that community for their entire life. Despite the large difference in migration status, the gender ratios in mining areas (51.9 percent) and in the rest of Zambia (51.4 percent) are almost identical, as is the average age (28.5 and 28.9, respectively).

Individuals in mining areas appear to engage in less sexual activity than individuals in the rest of Zambia. Marital rates (49 percent in mining areas versus 60 percent in the rest of Zambia), having any partner in the past twelve months (69 versus 76 percent), having multiple partners (7 versus 8 percent), having sex in the past month (56 versus 63 percent), and pregnancy rates (26 versus 33 percent) are lower in mining areas than in the rest of Zambia. Rates of transactional sex and unprotected sex are approximately the same in mining cities and in the rest of Zambia. The single exception to this general pattern is alcohol use before sex: 17 percent of respondents in mining cities report this behavior whereas only 9 percent of respondents in the rest of Zambia do so.

HIV prevalence is higher in mining areas (16.3 percent) than in the rest of Zambia (14.5 percent). Although lack of data on changes in HIV prevalence at the sub-province level means I cannot directly examine the effect of the copper boom on HIV prevalence, there exist data on HIV status in the 2007 DHS at the individual level so I am able to calculate HIV prevalence in mining areas and in the rest of Zambia. Higher HIV prevalence in mining areas might seem surprising given that the level and riskiness of sexual activity is not higher in mining areas than in the rest of Zambia. Urbanization, migration, and income are all correlated with mining areas and may be important factors in HIV transmission.

Districts on the copper transportation routes are more similar to the mining cities than is the rest of Zambia as a whole. Column (3) in Table 3 shows the average characteristics of districts on copper transportation routes. Although the mining cities are still richer than these districts, the divide is smaller for all consumer durable ownership rates except motorcycle ownership. For example, 51 percent of households in these districts have a high quality floor, 17 percent have a refrigerator, and 33 percent own a television. Similarly, residents of these districts have similar average demographic characteristics as mining cities: 19 percent of residents of these districts are migrants, 50.5 percent are female, and the average age is 28.7 years. Sexual behavior in districts on copper transportation routes is also closer to that in mining cities than sexual behavior in the rest of Zambia as whole.

Fifty-seven percent of residents in these districts are married, 73 percent report having any partner, 8 percent report multiple partners, 5 percent report transactional sex, 11 percent report alcohol use before sex, the rate of unprotected sex is 83 percent, 63 percent report having sex in the past month, and 30 percent report being pregnant. HIV prevalence is higher in these districts (16.5 percent) than in mining cities (16.3 percent), but the difference is smaller than that for the rest of Zambia as a whole.

Monthly data on mine-level copper output come from the Ministry of Mines and Minerals Development. These data are available for the period January 2000 through December 2008. Although I would like to complement the analysis of the effect of copper output with an analysis of the effects of employment in mining and of wages in mining, these data are not available at the mine level. Monthly data on the world copper price comes from the International Monetary Fund (IMF) database. The copper price series in the IMF database is the London Metal Exchange (LME) spot price for grade A cathode at CIF European ports.

6 Empirical Strategy

The main empirical strategy of this paper is to compare changes in sexual behavior associated with changes in copper output for individuals residing in mining areas to synchronous changes for individuals residing in non-mining areas. The basic premise of this approach is that the intensity of the copper shock was greater in copper mining areas than in other areas, both directly because of the increase in copper production and indirectly because of spill-over effects into other markets for local goods and services. The identifying assumption underlying this strategy is that in the absence of the copper boom these changes in sexual behavior (or material standard of living) in mining areas would have been the same as those in non-mining areas.

There are two primary concerns about the ability of this difference-in-differences-type strategy to identify the causal effect of the copper boom on sexual activity (or material standard of living) in mining areas. First, the copper boom may have affected sexual activity in non-mining areas as well, meaning that this strategy may yield a lower bound on the effect of the copper boom on sexual activity. I explore this possibility by examining the effect of excluding the non-mining areas most likely to be affected by the copper boom (i.e., the main transportation routes used for copper output) on the coefficient estimates. Second, there may have been unobservable shocks to sexual activity that were correlated spatially or temporally with changes in copper output. To address these concerns, I include district fixed effects, year fixed effects, and month fixed effects. In addition, the baseline empirical specification also includes a linear time trend and, in the (individual-level) sexual behavior regressions, gender and five-year age group fixed effects. Thus, the primary regression equation is

$$y_i = \gamma output_i + \alpha localmines_i + \beta localoutput_i + \xi X + \epsilon_i \tag{1}$$

where y_i denotes the outcome (i.e., measure of sexual activity in the past twelve months or measure of contemporaneous material standard of living) for individual i (or household i), $output_i$ is total copper production in Zambia in the twelve months leading up to the interview date, $localmines_i$ measures how many mines are in the area around the respondent, $localoutput_i$ measures total output in the area around the respondent, and X_i is a vector of individual-level, geographic, and time controls.

The baseline specification defines the area around each respondent as a circle with a radius of 10 kilometers centered at the reported location of the household.[9] As discussed in Section 2, there is a relatively large urban area located at (or very close to) each of the large-scale copper mines in Zambia. The effect of copper mining on behavior operates through markets and the urban area near each mine is a spatial approximation of the relevant market, so I assign the location of the output at each mine to be the approximate centroid of the nearest urban area. Thus, in practice the 10 kilometer radius means that the regressions compare individuals living in these urban areas at the mines to individuals living elsewhere in Zambia. In alternative specifications I relax the restriction that copper output has the same effect on behavior invariant of distance conditional on distance being greater than 10 kilometers.

This specification imposes a couple of simple restrictions that facilitate the exposition of the empirical results. First, in the absence of district fixed effects, equation (1) imposes the restriction that living within 10 kilometers of a mine has the same relationship with the outcome of interest (e.g., marital status) regardless of the identity of the mine. Including district fixed effects relaxes this restriction somewhat under the assumption that any heterogeneity across mines in this relationship is time invariant. Second, equation (1) imposes the restriction that changes in copper output within 10 kilometers of an individual have the

[9] This means that in practice *localmines* measures whether there is one mine within 10 kilometers of the respondent. The available data consist almost entirely of two types of households: households that live within 10 kilometers of exactly one mine and households that do not live within 10 kilometers of a mine. Only 0.09 percent of the sample is located within 10 kilometers of two mines and no respondents live within 10 kilometers of more than two mines.

same effect on the outcome of interest regardless of the identity of the mine. Alternatively, I am estimating the average effect of changes in copper output across the eleven mines.

7 Results

I begin the empirical analysis by examining the effect of the copper boom on consumer durable ownership. Then I examine the effect of the copper boom on migration and sexual behavior. As part of this analysis, I conduct a variety of robustness checks and explore heterogeneity by gender and age in the effects of the copper boom. Finally, I examine the role of selective in-migration in explaining these results.

The empirical results indicate that the copper boom reduced sexual activity. The results of the consumer durables and migration regressions clearly locate the effect of the copper boom in mining cities and suggest that there were not large effects in rural areas surrounding the mines or in the main non-mining urban areas (i.e., areas on the copper transportation routes) in Zambia. Sexual behavior regressions show that the copper boom caused a reduction in sexual activity and that this reduction was concentrated in the same locations that experienced an increased material standard of living and increased in-migration. A decomposition of the copper boom effect into compositional effects of selective in-migration to the mining cities and behavioral effects for non-migrants in the mining cities suggests that both mechanisms were important components of the overall reduction in sexual activity.

7.1 The Copper Boom and Household Consumer Durable Ownership

The regression results indicate that the copper boom increased the standard of living of households in mining areas. Estimates of the effects of copper output on consumer durable ownership appear in Table 4. All specifications include district fixed effects, year fixed effects, month fixed effects, and a linear time trend, as well as controls for total copper production in Zambia and the number of mines in the area around the respondent. Standard errors are clustered by Standard Enumeration Area (SEA) of residence.

Panel A presents the results from the baseline specification. These estimates indicate that the copper boom increased household ownership rates for many consumer durables, including improved flooring, refrigerators, televisions, and radios. The effects are statistically significant and are relatively large. The estimates indicate that a one standard deviation increase in copper output in the past year within 10 kilometers of a household (i.e., 21,000 metric tons) increased ownership rates for these consumer durables by between 2 and 6 percentage points. In relative terms, these are fairly large effects. For example, a one standard deviation in copper output increased the probability of having a high quality floor by 15 percent relative to the average for Zambia as a whole. The copper boom had little-to-no effect on vehicle ownership rates. However, this is not so surprising because cars are more expensive than the other consumer durables, bicycles may not be normal goods in this income range, and very few Zambians own motorcycles.

The effect of the copper boom on the material standard of living appears to have diminished rapidly with distance from a mining city. Panel B presents the results from an expanded specification that includes output within 10-20 kilometer and 20-30 kilometer bands of the household, as well as control variables for the number of mines within 10-20 kilometers and within 20-30 kilometers. The estimated effects of copper output in these bands are much smaller than those found within a 10 kilometer radius of the household, sometimes the coefficient estimates are negative, and in most cases they are statistically insignificant. In the 10-20 kilometer band, the estimated effects of copper output on floor quality and television ownership are close to zero. However, copper output has a statistically significant and positive effect on refrigerator/radio ownership and the effect on radio ownership is larger than in the 0-10 kilometer band. As in the 0-10 kilometer band, copper output has virtually no effect on vehicle ownership rates. In the 20-30 kilometer band, copper output is actually negatively correlated with consumer durables ownership rates, with one exception: bicycle ownership. However, the coefficient estimate is statistically significant for only two of the four non-vehicle consumer durables (i.e., the consumer durables that were related to copper output in the 10 kilometer circle) and for all four measures the coefficient estimate is smaller in absolute value. Thus, the coefficient estimates in Panel B present a clear pattern: the effect of the copper boom on consumer durable ownership rates diminished rapidly with distance from a mining city.

The coefficient estimates in Panels A and B may be underestimates of the effect of the copper boom on the material standard of living in mining areas. If the copper boom raised the material standard of living in non-mining areas as well, then the estimates in Panels A and B may be biased downwards. To explore this possibility, Panel C excludes respondents who live along the copper transportation corridors. These corridors are: (i) the route south from the copper mining region to Lusaka and on to Livingstone, and (ii) the route from the copper mining region to the east and on past Kasama. Households in these areas would appear to be those households outside of the copper mining region most likely to have benefited from increased copper production.[10]

[10] I exclude the following districts from the regressions in Panel C: Chibombo, Chinsola, Choma, Isoka, Kabwe, Kafue, Kalomo, Kapiri Mposhi, Kasama, Kazungula, Livingstone, Lusaka, Masaiti, Mazabuka,

The estimated effects of the copper boom on the material standard of living in mining areas are robust to excluding districts along the copper transportation corridor. All of the effects identified in the baseline specification (i.e., Panel A) are present in Panel C. For some consumer durables measures (e.g., floor) the estimated effects are slightly larger in Panel C than in Panel A, suggesting that districts along transportation corridors may have benefited from the copper boom. However, these differences are not large.

7.2 The Copper Boom and Individual Behavior: Sexual Activity and Migration

7.2.1 Baseline Results

The regression results indicate that the copper boom reduced sexual activity in mining areas. Estimates of the effects of copper output on sexual activity appear in Table 5. All specifications include year fixed effects, district fixed effects, season fixed effects, and a linear time trend, as well as controls for total copper production in Zambia and the number of mines in the area around the respondent. Standard errors are clustered by Standard Enumeration Area (SEA) of residence.

Panel A presents the results from the baseline specification. These estimates indicate that the copper boom reduced sexual activity of many kinds in mining cities; particularly risky sexual activity such as transactional sex and multiple partnerships and seemingly less risky activity such as marriage. The estimates indicate that a one standard deviation increase in copper output in the past year within 10 kilometers of a household (i.e., 21,000 metric tons) reduces sexual activity by approximately 1 percentage point, regardless of the measure of sexual activity. Although the magnitude of these effects is not particularly large in absolute terms, they largely are statistically significant. Moreover, the effects in relative terms for the riskiest activities (i.e., transactional sex and multiple partnerships) are quite large. An increase of one standard deviation in copper output in the past year within 10 kilometers of a household reduces multiple partnerships by approximately 14 percent and transactional sex by approximately 25 percent.

The consumer durables findings from the previous section suggest that the effect of the copper boom on sexual activity may be limited primarily to the mining cities. Panel B presents the results from an expanded specification that includes output within 10-20 kilometer and 20-30 kilometer bands of the household, as well as control variables for the number of mines within 10-20 kilometers and the number of mines within 20-30 kilometers.

Mkushi, Monze, Mpika, Nakonde, and Sernje.

As in the consumer durables regressions, including the 10-20 kilometer and 20-30 kilometer bands has little effect on the coefficient estimates for copper output within 0-10 kilometers of the respondent or the standard errors. Perhaps surprisingly, the estimated effects of copper output in the 10-20 kilometer band are often larger in absolute value than those for output in a 10 kilometer radius. For example, a 100,000 metric ton increase in copper output 10-20 kilometers from the respondent reduces the probability of engaging in transactional sex by 10.6 percent, whereas a 100,000 metric ton increase in copper output within 10 kilometers of the respondent reduces the probability of engaging in transactional sex by 6.5 percent. However, these effects virtually disappear for copper output 20-30 kilometers from the respondent. The estimated effects of copper output in the 20-30 kilometer band are smaller in absolute value than those for copper output within 10 kilometers of the respondent and the effects in the 20-30 kilometer band are almost always statistically insignificant. This general pattern of a diminishing effect of copper output on sexual activity with respect to distance from the center of a copper mining city is similar to the pattern documented for the effect of copper output on consumer durables ownership rates in the previous section.

The coefficient estimates in Panels A and B might reflect an increase in sexual activity in non-mining areas rather than a decrease in sexual activity in mining areas. Oster (2009a) provides evidence from Sub-Saharan Africa that increases in exports and associated trucking activity are linked to increases in HIV incidence. If the copper boom induced an increase in sexual activity along copper transportation routes, the regressions in Panels A and B might show a negative effect of copper output on sexual activity in mining areas even if there was actually no effect on sexual activity in mining areas. To explore this hypothesis, Panel C excludes respondents who live along the copper transportation corridors.

The estimated effects of the copper boom on sexual activity in mining areas are robust to excluding districts along the copper transportation corridor. All of the effects identified in the baseline specification (i.e., Panel A) are present in Panel C. Neither the point estimates nor the standard errors vary much across these two specifications. The most noticeable difference is that the estimated effect of a 100,000 metric ton increase in copper output within 10 kilometers of the respondent on the probability of being pregnant increases (in absolute value) from -6.9 percentage points to -7.8 percentage points.

As part of the analysis of individual-level behavioral response to the copper boom, I examine the effect of the copper boom on in-migration. Column (9) of Table 5 presents the in-migration results. As shown in Panel A, the copper boom induced in-migration to the copper mining cities. A one standard deviation increase in copper output in a given mining city increased the probability a resident was a recent in-migrant by 2.7 percentage points, or by roughly 10 percent as compared to the baseline proportion of in-migrants. The results in Panels B and C indicate that the in-migration effect was seemingly limited to the copper mining cities. Output within 10-20 kilometers or within 20-30 kilometers has virtually no net effect on in-migration and excluding districts on copper transportation routes (districts that plausibly experienced substantial copper boom induced in-migration) has no effect on the estimated effect of the copper boom on in-migration in mining cities.

7.2.2 Gender

Males and females may not have responded to the copper boom in the same way. Table 6 allows the effect of copper output on sexual activity to vary by gender of the respondent. The estimates suggest that the copper boom decreased sexual activity more for males than for females, although the gender difference rarely is statistically significant. For most measures of sexual activity, the estimated effects for females are roughly between one-quarter to three-quarters the magnitude of the effects for males. Although the presumption is that the vast majority of reported sexual activity in Zambia is heterosexual, differential effects by gender are not ruled out because the survey data may under-sample high frequency females and many of the measures of sexual activity are truncated. It may be the case that the under-sampled high frequency women are reducing their sexual activity by more than the women in the sample. In addition, the measures of sexual activity mostly capture the extensive margin of sexual behavior decision-making and do not capture the intensive margin. It may be the case that the intensive margin decreases more for women than for men. Either of these two explanations might reconcile the gender difference in the response to the copper boom.

Disaggregating the in-migration response by gender has little impact on the estimated effect of the copper boom. Although the effect is somewhat larger for males, the difference by gender is not statistically significant. This suggests that the copper boom attracted female and male in-migrants in roughly equal proportions.

7.2.3 Age

The effect of the copper boom on sexual activity may have varied across age groups. Table 7 examines this possibility by reporting the coefficient estimates on a female indicator variable, age-group indicator variables, and the interactions of these two sets of variables. These estimates indicate that the effect of copper output on sexual activity was concentrated among younger age groups (i.e., females age 15-19 and males ages 15-19 and 20-29). This is not surprising. Over 70 percent of individuals age 20 or older are already married, so it should be expected that marriage among older individuals would not be particularly responsive to the economic shock. Also, females age 15-19 and males ages 15-19 and 20-29 have the highest rates of transactional sex and hence the greatest scope for reduction. Similarly, the propensity for multiple partnerships peaks at age 15-19 for females and age 20-29 for males.

Disaggregating the in-migration response by the interaction of age and gender suggests that younger individuals may have been more likely to migrate to copper mining cities in response to the boom. Older males (e.g., ages 30-39 and 40-49) were slightly less likely to demonstrate a change in the probability of being an in-migrant. Females in the middle of the age distribution (i.e., ages 20-29) were also less likely to demonstrate a change in the probability of being an in-migrant. However, none of these differences are statistically significant at conventional levels.

7.3 Selection and Effects on Non-Migrants

Substantial in-migration in mining areas induced by the copper boom raises two important points about the results presented thus far. First, selective in-migration may have contributed to the overall reduction in sexual activity due to the copper boom. Second, self-reported sexual activity among in-migrants may partly reflect the respondent's behavior in the previous (i.e., non-mining) location. This section addresses these issues in detail by comparing the behavior of in-migrants and non-migrants, as well as by examining the effect of the copper boom on sub-samples of non-migrants.

A simple comparison of means indicates that migrants in mining areas are different from non-migrants in mining areas. As shown in Table 8, migrants in mining cities are younger, more likely to be female, and less likely to be married as compared to non-migrants in mining cities. For most measures of sexual activity, in-migrants appear to engage in less sexual activity than non-migrants. For example, 57 percent of non-migrants report having had sex in the past month, whereas 50 percent of migrants report having had sex in the past month. Similarly, 5 percent of non-migrants report engaging in transactional sex, whereas 3 percent of migrants report engaging in transactional sex. Two exceptions are pregnancy and having any partner. Twenty-four percent of female non-migrants report being pregnant compared to thirty-five percent of female in-migrants. Sixty-nine percent of non-migrants report having any partner compared to seventy percent of in-migrants. Aside from bicycles, there do not appear to be large differences between migrants and non-migrants in consumer durables ownership rates. Because in-migrants appear to be less risky than non-migrants along many dimensions, compositional changes associated with in-migration induced by the copper boom seem to explain some of the reduction in sexual activity.

Although copper boom induced in-migration appears to have had a compositional effect on sexual activity, the copper boom still may have affected the behavior of non-migrants residing in mining areas. To verify this hypothesis, I estimate the effects of the copper boom on consumer durables ownership and sexual behavior using a restricted sample of individuals who have resided in the same location for at least five years. I choose five years because the portion of the copper boom captured in the survey data used in this analysis lasted for five years. Thus, this choice of sample ensures that I am omitting any individuals induced to move because of the copper boom. This sample specification means that I comparing the change in consumer durables/sexual behavior associated with the timing of the copper boom for individuals residing for at least five years in the same mining area household to the change for individuals residing for at least five years in the same non-mining area household. As an additional check, I relax this restriction and omit only those individuals who report residing in the same household for less than twelve months. This sample specification ensures that the sexual activity occurred during the period the respondent was resident in a mining area, while capturing most, although not all, of the copper boom migrants.

Table 9 presents the consumer durables results for the two restricted samples of non-migrants. These regressions include the same set of controls as the regressions estimated using the full sample. Panel A shows the results for the sub-sample of respondents who have resided in the same household for at least five years. Panel B shows the results for the sub-sample of respondents who have resided in the same household for at least twelve months. Both sets of estimates are similar to those found in the baseline sample (i.e., the results presented in Table 4). Among non-migrants, the copper boom had large effects on floor quality, television ownership, and refrigerator ownership. Furthermore, these effects are larger when I relax the definition of non-migrant. For example, consider the floor quality regression. In the full sample the coefficient on copper output within 10 kilometers of the respondent is 0.293 (see Panel A in Table 4), excluding individuals who moved within the past twelve months increases this coefficient to 0.324 (see Panel B in Table 9), and excluding individuals who moved within the past five years increases this coefficient to 0.373 (see Panel A in Table 9). The noticeable exception to this pattern is radio ownership. Although the effect on radio ownership is not statistically significant at conventional levels, the point estimates are very close to that found using the baseline sample. In general, these results confirm that non-migrants in mining areas did receive a positive economic shock, a finding that should not be surprising.

Table 10 presents the sexual behavior results for the restricted samples of non-migrants. These regressions include the same set of controls as the regressions estimated using the full sample. As in the previous table, Panel A shows the results for the sub-sample of respondents who have resided in the same household for at least five years and Panel B shows the results for the sub-sample of respondents who have resided in the same household for at least twelve months. The estimated effects of the copper boom on sexual activity for non-migrants typically are smaller than the estimates for the pooled sample. For example, in the marriage regression the coefficient on copper output within 10 kilometers of the respondent falls (in absolute value) from -0.074 in the full sample to -0.043 in Panel A. Similarly, the coefficient in the pregnancy regression falls (in absolute value) from -0.069 in the full sample to -0.010 in Panel A. For the riskier activities (e.g., multiple partnerships and transactional sex), the coefficient estimates are less sensitive to restricting the regression to non-migrants. For multiple partnerships, the coefficient estimate in Panel A, -0.038, is virtually the same as in the full sample. For transactional sex, the coefficient estimate in Panel A (-0.045) is somewhat smaller than that estimated using the full sample (-0.059). The coefficient estimates in Panel B are roughly similar to those in Panel A. The most noticeable difference is that copper output has a large and statistically significant negative effect on pregnancy rates, an effect that is similar in magnitude to that estimated using the full sample.

8 Conclusion

This paper provides evidence on the effect of a large and sustained economic shock on sexual behavior and the spread of HIV/AIDS. I exploit the dramatic increase in the world copper price in the early 21st century, a change that was exogenous to the process determining sexual behavior in Zambia, to credibly identify the general equilibrium effects of increased production in a major sector of the Zambian economy on sexual behavior. I use newly assembled repeated cross-sectional sexual behavior survey data with a detailed geographic component collected before and during the copper boom and employ a host of spatial and temporal controls to address remaining concerns about identification.

In the setting I examine, Zambia during the early 21st century copper boom, a large positive economic shock to copper production reduced sexual activity, including the riskiest sexual activities (e.g., transactional sex). This suggests that continued economic growth in

Sub-Saharan Africa is likely to be an important factor in the fight against the HIV/AIDS pandemic. However, the effect of long-run economic growth on sexual behavior and the spread of HIV/AIDS may differ from that of (even a sustained) positive economic shock so additional research on this question is required.

9 References

Beny, Laura and Lisa Cook. 2009. Metals or management? Explaining Africa's recent economic growth performance. American Economic Review: Papers & Proceedings, 99(2): 268-274.

Central Statistics Office. 2005 Labor Force Survey. Government of Zambia.

Dinkelman, Taryn, David Lam, and Murray Leibbrandt. 2007. Household and community income, economic shocks and risky sexual behavior of young adults: Evidence from the Cape Area Panel Study 2002 and 2005. AIDS, 21(supplement 7): S49-S56.

Edlund, Lena and Evelyn Korn. 2002. A theory of prostitution. Journal of Political Economy, 110(1): 181-214.

Fenton, Lynda. 2004. Preventing HIV/AIDS through poverty reduction: The only sustainable solution. Lancet, 364: 1186-87.

Fortson, Jane. 2009. HIV/AIDS and fertility. American Economic Journal: Applied Economics, 1(3): 170-194.

Fortson, Jane. 2010. Mortality risk and human capital investment: The impact of HIV/AIDS in Sub-Saharan Africa. Review of Economics and Statistics, forthcoming.

Fraser, Alastair and John Lungu. 2007. For Whom the Windfalls? Winners and Losers in the Privatization of Zambia's Copper Mines. Lusaka, Zambia: Mine Watch Zambia.

Gertler, Paul, Manisha Shah, and Stefano Bertozzi. 2005. Risky business: The market for unprotected commercial sex. Journal of Political Economy, 113(4): 518-550.

Gersovitz, Mark, Jacoby, Hanan, Seri Dedy, F., Goze Tape, A.. 1998. The balance of self-reported heterosexual activity in KAP surveys and the AIDS epidemic in Africa. Journal of the American Statistical Association, 93(443): 875-883.

International Copper Study Group. www.icsg.org. Accessed January 2010.

Juhn, Chinhui, Sebnem Kalemi-Ozcan, Belgi Turan. 2009. HIV and fertility in Africa: First evidence from population based surveys. NBER Working Paper 12181.

Lurie, Mark, Brian Williams, Khangelani Zuma, David Mkaya-Mwamburi, Geoff Garnett, Michael Sweat, Joel Gittlesohn, and Salim Abdool Karim. Who infects whom? HIV-1 concordance and discordance among migrant and non-migrant couples in South Africa. AIDS, 17: 2245-2252.

Mishra, Vinod, Simona Bignami-Van Assche, Robert Greener, Martin Vaessen, Rathavuth Hong, Peter Ghys, J. Ties Boerma, Ari Van Assche, Shane Khan, and Shea Rutstein. 2007. HIV infection does not disproportionately affect the poorer in Sub-Saharan Africa. AIDS, 21 (suppl 7): S17-S28.

Oster, Emily. 2009a. Routes of infection: Exports and HIV incidence in Sub-Saharan Africa. Unpublished manuscript.

Oster, Emily. 2009b. HIV and behavior change: Why not Africa? Unpublished manuscript.

Panayotou, Theodore. 1979. OPEC as a model for copper exporters: Potential gains and cartel behavior. The Developing Economies, 17(2): 203-219.

Parkhurst, Justin. 2010. Understanding the correlations between wealth, poverty and human immunodeficiency virus infection in African countries. Bulletin of the World Health Organization, 88: 519-526.

Pindyck, Robert. 1978. Gains to producers from the cartelization of exhaustible resources. The Review of Economics and Statistics, 60(2): 238-251.

Robinson, Jonathan and Ethan Yeh. 2010. Transactional sex as a response to risk in Western Kenya. American Economic Journal, forthcoming.

Stuckler, David, Basu, Sanjay, McKee, Martin, and Mark Lurie. 2010. Mining and risk of tuberculosis in Sub-Saharan Africa. Forthcoming, American Journal of Public Health.

United Nations Statistics Division. Commodity Trade Statistics Database. www.data.un.org. Accessed October 2009.

United States Agency for International Development (USAID). 2006. Zambia: Economic Performance Assessment. March, 2006.

Young, Alwyn. 2005. The gift of the dying: The tragedy of AIDS and the welfare of future African generations. Quarterly Journal of Economics, 120(2): 423-466.

Figure 1: Spatial Distribution of Copper Mining in Zambia

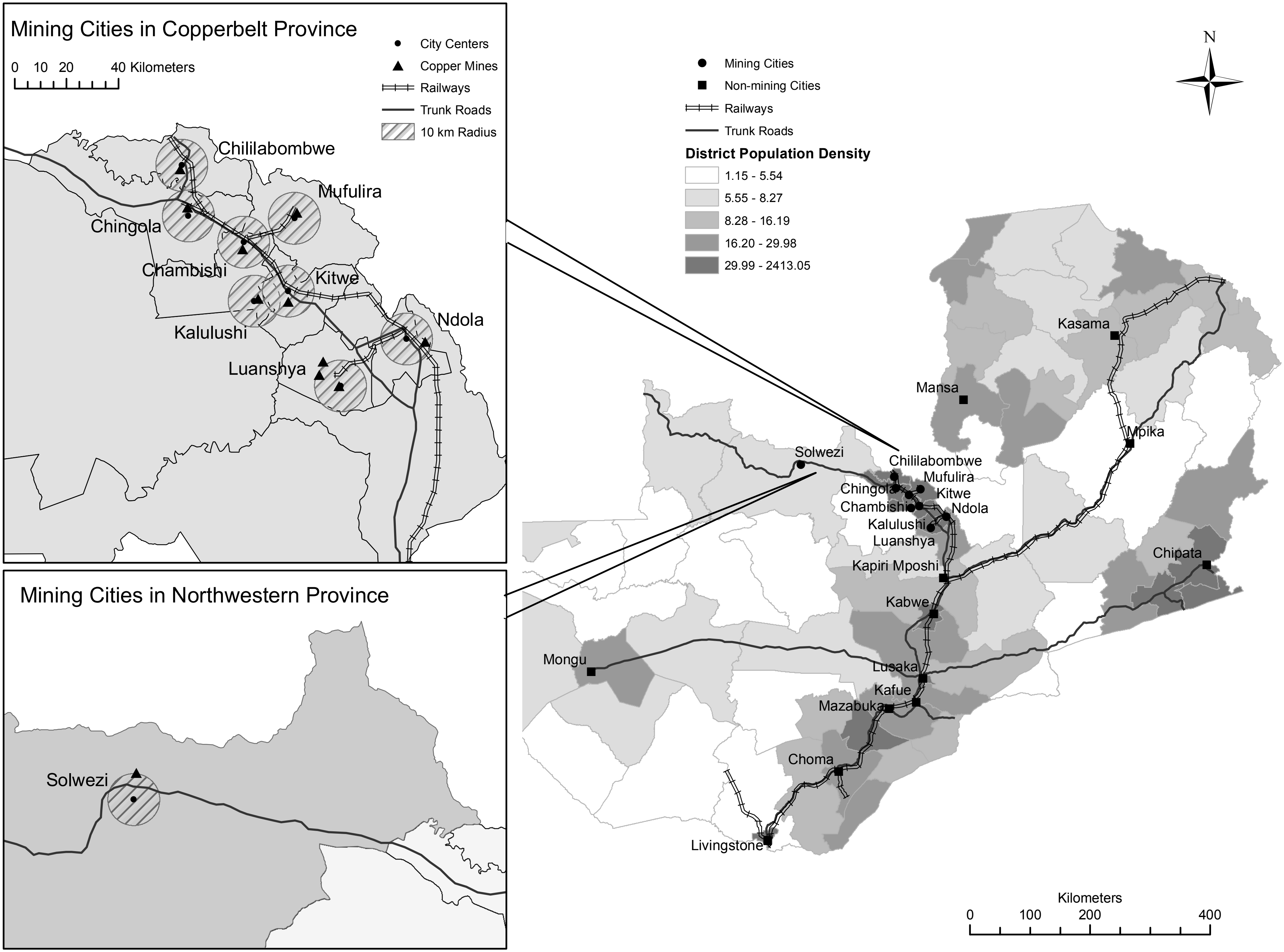
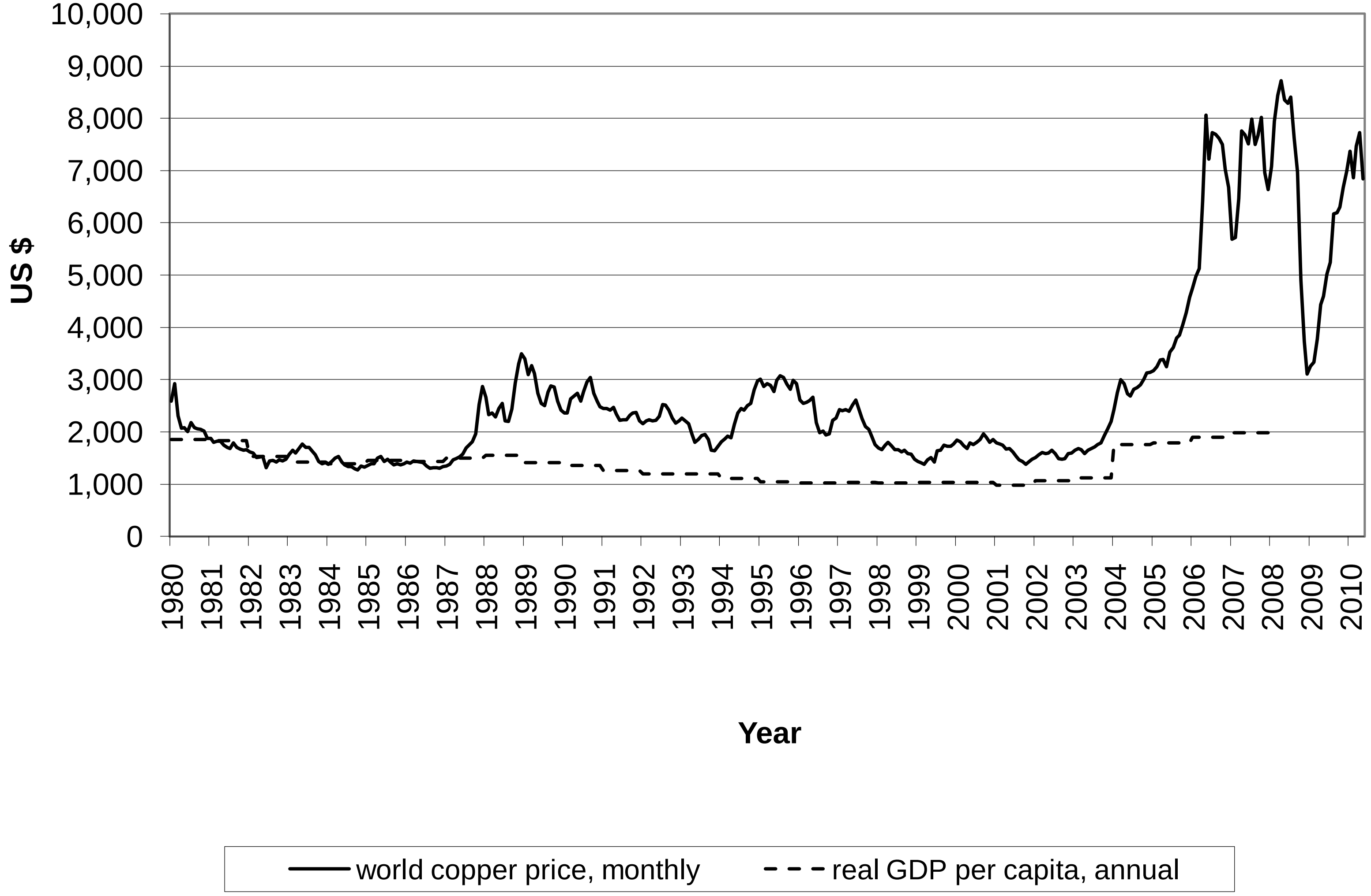


Figure 2: World Copper Price and Zambia GDP per capita, 1980-2010



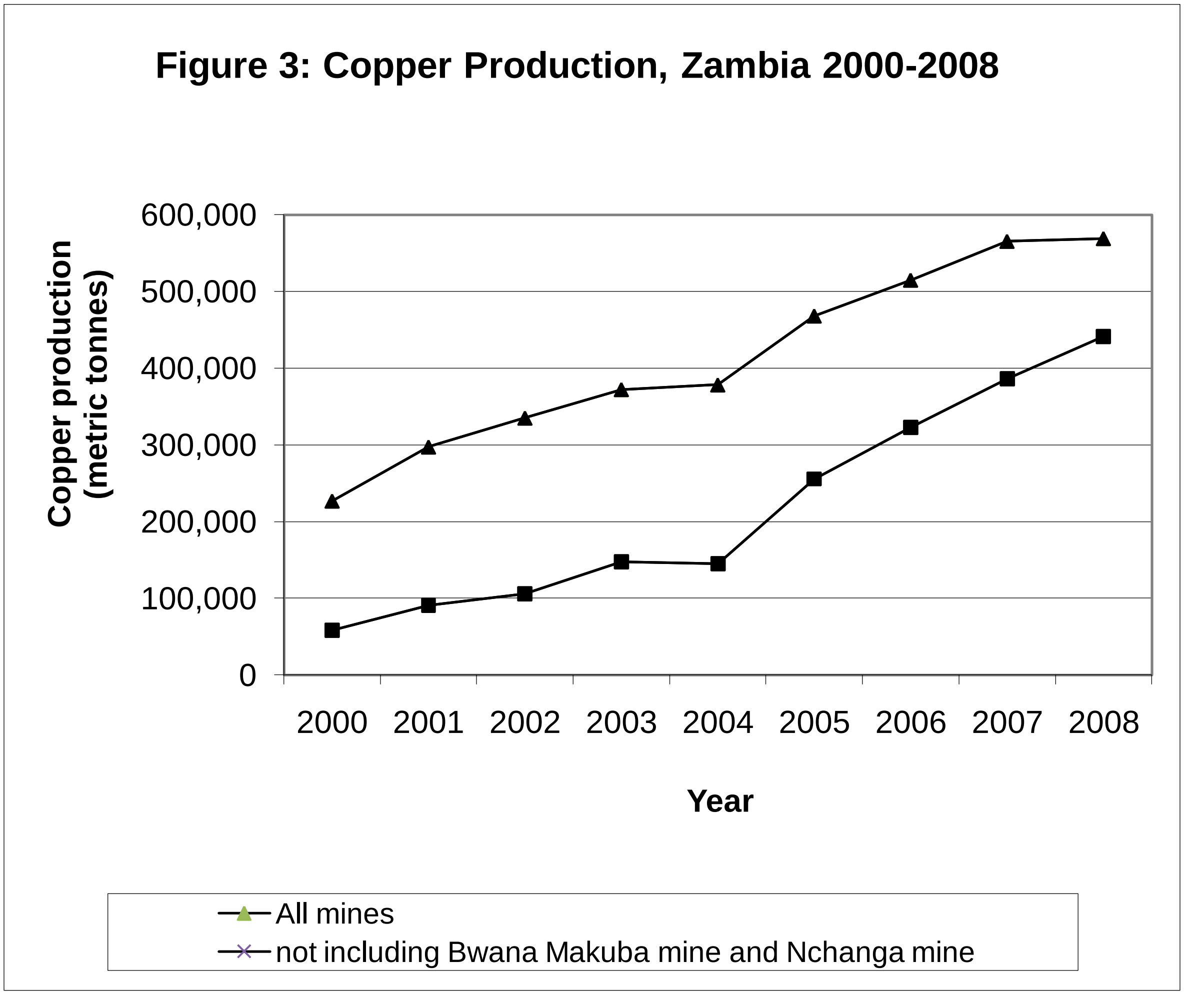


Figure 3: Copper Production, Zambia 2000-2008
Copper production (metric tonnes)
600,000
500,000
400,000
300,000
200,000
100,000
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year
All mines
not including Bwana Makuba mine and Nchanga mine

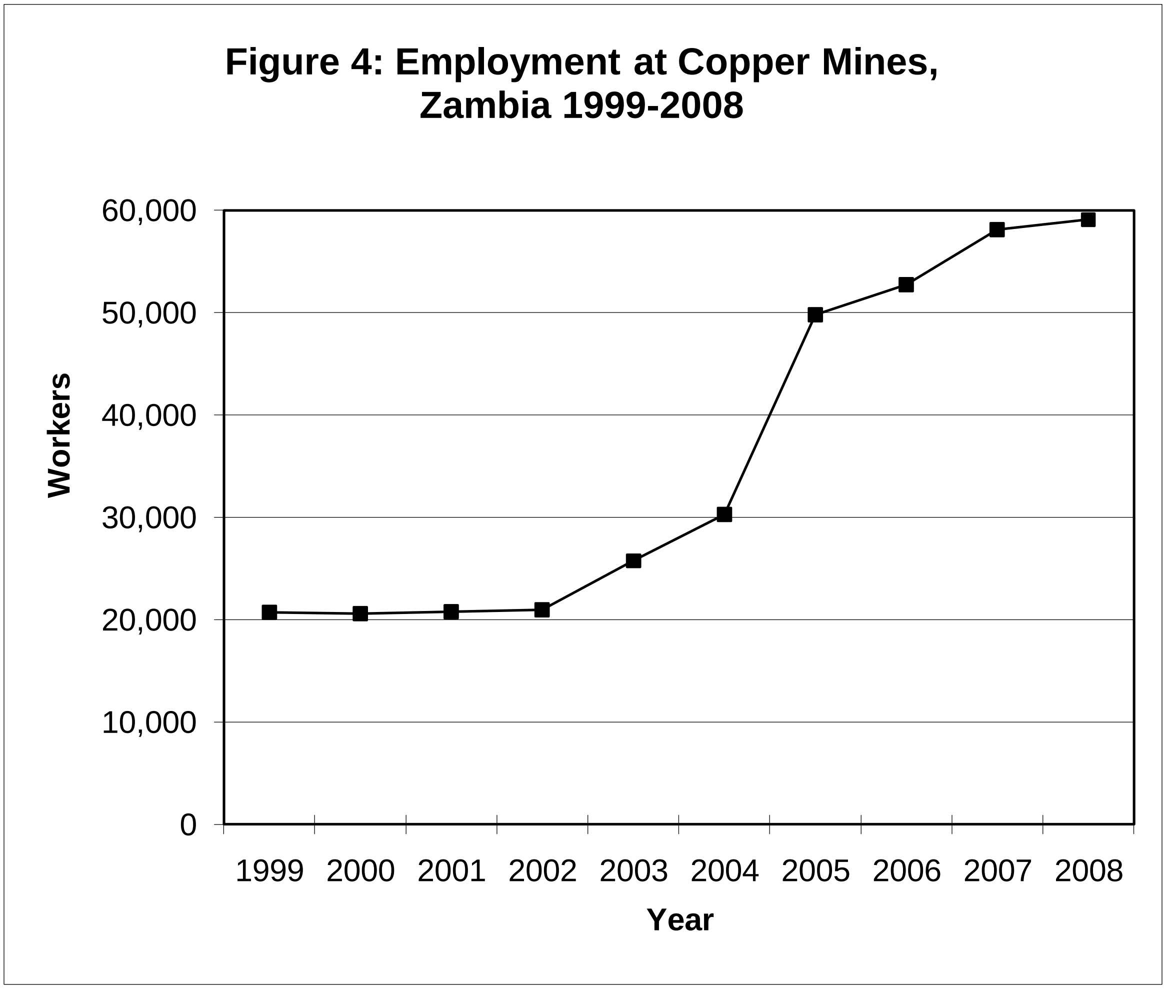


Figure 4: Employment at Copper Mines,
Zambia 1999-2008
Workers
60,000
50,000
40,000
30,000
20,000
10,000
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

Table 1: City Sizes in Zambia, 2000

city	population	rank	mining city
Lusaka	1,084,703	1	no
Ndola	374,757	2	yes
Kitwe	363,734	3	yes
Kabwe	176,758	4	no
Chingola	147,448	5	yes
Mufulira	122,336	6	yes
Luanshya	115,579	7	yes
Livingstone (Maramba)	97,488	8	no
Kasama	74,243	9	no
Chipata	73,110	10	no
Chililabombwe	54,504	11	yes
Kalulushi	52,770	12	yes
Mazabuka	47,148	13	no
Kafue	45,890	14	no
Mongu	44,310	15	no
Mansa	41,059	16	no
Choma	40,405	17	no
Solwezi	38,121	18	yes
Kapiri Mposhi	27,219	19	no
Mpika	25,856	20	no

Source: 2000 Census.

Table 2: Mean Sexual Behavior by Age and Gender of DHS and ZSBS Respondents

Sexual behavior:	married	any partner	multiple partners	money	alcohol	proportion unprotected	sex in past month	pregnant
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Females								
Age								
15-19	0.20	0.42	0.021	0.052	0.04	0.79	0.44	0.22
20-24	0.65	0.81	0.020	0.034	0.10	0.85	0.61	0.42
25-29	0.76	0.88	0.020	0.022	0.14	0.88	0.66	0.44
30-34	0.77	0.88	0.014	0.020	0.14	0.91	0.66	0.39
35-39	0.78	0.83	0.010	0.014	0.13	0.93	0.64	0.30
40-44	0.73	0.78	0.016	0.014	0.13	0.93	0.60	0.15
45-49	0.72	0.74	0.008	0.007	0.11	0.96	0.59	0.04
15-49	0.61	0.74	0.017	0.028	0.11	0.88	0.61	0.32
Panel B: Males								
Age								
15-19	0.01	0.32	0.059	0.066	0.02	0.64	0.31	-
20-24	0.28	0.69	0.153	0.096	0.07	0.65	0.48	-
25-29	0.70	0.90	0.201	0.074	0.13	0.75	0.67	-
30-34	0.84	0.94	0.195	0.054	0.14	0.84	0.75	-
35-39	0.88	0.94	0.193	0.046	0.14	0.85	0.75	-
40-44	0.89	0.94	0.174	0.029	0.14	0.90	0.74	-
45-49	0.91	0.94	0.166	0.025	0.12	0.93	0.79	-
50-54	0.90	0.92	0.134	0.013	0.12	0.92	0.74	-
55-59	0.90	0.91	0.115	0.020	0.11	0.95	0.74	-
15-59	0.56	0.76	0.151	0.059	0.10	0.80	0.64	-

Notes: Data come from the 2001 and 2007 DHS survey rounds and the 2003 and 2005 ZSBS survey rounds.
Married is an indicator variable equal to one if the respondent was married at the time of the survey.
Any partner is an indicator variable equal to one if the respondent had any sexual partner in the past twelve months.
Multiple partners is an indicator variable equal to one if the respondent had more than one partner.
Money is an indicator variable equal to one if the respondent engaged in transactional sex.
The ZSBS asks all respondents to report whether they engaged in transactional sex.
The DHS only asks male respondents whether they engaged in transactional sex.
Alcohol is an indicator variable equal to one if the respondent consumed alcohol before sex.
Proportion unprotected is defined as the proportion of reported sex acts that were committed without using a condom.
Sex in the past month is an indicator variable equal to one if the respondent had sex in the past month.
Pregnant is an indicator variable equal to one if the respondent reported being pregnant at any time in the past twelve months.

Table 3: Mean Characteristics of DHS and ZSBS Respondents by Location

Sample:	mining cities	rest of Zambia	districts on copper transportation routes
	(1)	(2)	(3)
Consumer durables			
Floor	0.73	0.34	0.51
Refrigerator	0.28	0.11	0.17
Television	0.49	0.21	0.33
Radio	0.66	0.56	0.62
Car	0.05	0.03	0.04
Motorcycle	0.00	0.00	0.01
Bicycle	0.27	0.41	0.40
Demographic characteristics			
Migrant	0.22	0.17	0.19
Female	51.9	51.4	50.5
Age	28.5	28.9	28.7
Sexual behavior			
Married	0.49	0.60	0.57
Any partner	0.69	0.76	0.73
Multiple partners	0.07	0.08	0.08
Money exchanged	0.05	0.05	0.05
Alcohol use at sex	0.17	0.09	0.11
Proportion unprotected sex	0.83	0.84	0.83
Sex in past month	0.56	0.63	0.63
Pregnant	0.26	0.33	0.30
Health			
HIV positive	0.163	0.145	0.165

Notes: Data come from the 2001 and 2007 DHS survey rounds and the 2003 and 2005 ZSBS survey rounds.
Data on HIV status come from a single cross-section, the 2007 DHS.
Floor is an indicator variable for improved floor.
Refrigerator, television, radio, car, motorcycle, and bicycle are also indicator variables.
Migrant is an indicator variable equal to one if the respondent had resided in the same household for less than twelve months at the time of the interview date.
A mining city is defined as the area within a 10 kilometer radius of the approximate centroid of the urban area around each mining agglomeration.
The districts on the copper transportation routes are: Chibombo, Chinsola, Choma, Isoka, Kabwe, Kafue, Kalomo, Kapiri Mposhi, Kasama, Kazungula, Livingstone, Lusaka, Masaiti, Mazabuka, Mkushi, Monze, Mpika, Nakonde, and Sernje.

Table 4: Effect of Copper Boom on Household Consumer Durable Ownership, 2001-2007

Dependent variable:	floor	refrigerator	television	radio	car	motorcycle	bicycle
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Baseline specification							
CU output, 0-10km	0.293	0.220	0.310	0.141	0.021	-0.002	-0.111
	(0.145)	(0.087)	(0.116)	(0.084)	(0.023)	(0.002)	(0.104)
Observations	11,419	11,449	11,456	11,471	11,444	11,445	11,451
Panel B: Additional bands							
CU output, 0-10km	0.273	0.231	0.295	0.120	0.019	-0.003	-0.112
	(0.144)	(0.088)	(0.116)	(0.079)	(0.023)	(0.002)	(0.109)
CU output, 10-20km	-0.018	0.156	-0.002	0.178	-0.001	-0.001	0.105
	(0.139)	(0.097)	(0.112)	(0.060)	(0.014)	(0.002)	(0.075)
CU output, 20-30km	-0.194	-0.057	-0.158	-0.083	-0.010	-0.004	0.021
	(0.103)	(0.083)	(0.093)	(0.070)	(0.017)	(0.002)	(0.077)
Observations	11,419	11,449	11,456	11,471	11,444	11,445	11,451
Panel C: Comparison group excludes districts on copper transportion routes							
CU output, 0-10km	0.328	0.246	0.347	0.175	0.025	-0.001	-0.122
	(0.156)	(0.091)	(0.119)	(0.088)	(0.023)	(0.002)	(0.105)
Observations	7,334	7,353	7,356	7,368	7,349	7,350	7,353

Notes: Data come from the 2001 and 2007 DHS survey rounds and the 2003 and 2005 ZSBS survey rounds.
Floor is an indicator variable for improved floor.
Refrigerator, television, radio, car, motorcycle, and bicycle are also indicator variables.
CU output, or copper output, is measured in '00,000s of metric tons.
Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).
All specification include controls for total copper output in all of Zambia and for the number of mines with 10km.
All specifications include year fixed effects, month fixed effects, district fixed effects, and a linear time trend.
Panel C excludes the following districts: Chibombo, Chinsola, Choma, Isoka, Kabwe, Kafue, Kalomo, Kapiri Mposhi, Kasama, Kazungula, Livingstone, Lusaka, Masaiti, Mazabuka, Mkushi, Monze, Mpika, Nakonde, and Sernje.

Table 5: Effect of Copper Boom on Sexual Behavior and In-Migration, 2001-2007

Dependent variable:	married	any partner	multiple partners	money	alcohol	proportion unprotected	sex in past month	pregnant	resident less than one year
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Baseline specification									
CU output, 0-10km	-0.074	-0.047	-0.040	-0.059	-0.062	-0.035	-0.053	-0.069	0.133
	(0.038)	(0.030)	(0.023)	(0.026)	(0.037)	(0.044)	(0.035)	(0.036)	(0.053)
Observations	25,171	25,171	25,171	16,301	21,501	18,646	21,831	12,953	25,135
Panel B: Additional bands									
CU output, 0-10km	-0.070	-0.050	-0.046	-0.065	-0.043	-0.031	-0.047	-0.058	0.143
	(0.035)	(0.030)	(0.023)	(0.026)	(0.042)	(0.043)	(0.033)	(0.035)	(0.056)
CU output, 10-20km	-0.091	-0.078	-0.040	-0.106	0.115	-0.005	-0.042	-0.030	0.075
	(0.026)	(0.035)	(0.027)	(0.018)	(0.035)	(0.048)	(0.053)	(0.053)	(0.069)
CU output, 20-30km	0.069	-0.015	-0.007	0.007	0.078	0.091	0.093	0.012	-0.002
	(0.037)	(0.035)	(0.024)	(0.020)	(0.035)	(0.045)	(0.060)	(0.039)	(0.063)
Observations	25,171	25,171	25,171	16,301	21,501	18,646	21,831	12,953	25,135
Panel C: Comparison group excludes districts on copper transportation routes									
CU output, 0-10km	-0.069	-0.048	-0.045	-0.058	-0.058	-0.054	-0.047	-0.078	0.135
	(0.037)	(0.032)	(0.023)	(0.026)	(0.038)	(0.044)	(0.036)	(0.036)	(0.054)
Observations	15,581	15,581	15,581	9,873	13,248	11,727	13,702	8,104	15,554

Notes: Data come from the 2001 and 2007 DHS survey rounds and the 2003 and 2005 ZSBS survey rounds.
CU output, or copper output, is measured in '00,000s of metric tons.
Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).
All specifications include indicator variables for female and for five-year age groups.
All specifications include controls for total copper output in all of Zambia and for the number of mines within 10km.
All specifications include year fixed effects, month fixed effects, district fixed effects, and a linear time trend.
Panel C excludes the following districts: Chibombo, Chinsola, Choma, Isoka, Kabwe, Kafue, Kalomo, Kapiri Mposhi, Kasama, Kazungula, Livingstone, Lusaka, Masaiti, Mazabuka, Mkushi, Monze, Mpika, Nakonde, and Sernje.

Table 6: Heterogeneity by Gender in Effect of Copper Boom on Sexual Behavior and In-Migration, 2001-2007

Dependent variable:	married	any partner	multiple partners	money	alcohol	proportion unprotected	sex in past month	pregnant	resident less than one year
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CU output, 0-10km	-0.100	-0.078	-0.055	-0.068	-0.128	-0.041	-0.110	-0.061	0.161
	(0.039)	(0.038)	(0.028)	(0.029)	(0.041)	(0.040)	(0.035)	(0.034)	(0.058)
Female*CU output, 0-10km	0.056	0.061	0.023	0.042	0.135	0.011	0.116		-0.045
	(0.044)	(0.040)	(0.029)	(0.035)	(0.057)	(0.033)	(0.044)		(0.051)
Observations	25,171	25,171	25,171	16,301	21,501	18,646	21,831	12,953	25,135

Notes: Data come from the 2001 and 2007 DHS survey rounds and the 2003 and 2005 ZSBS survey rounds.
CU output, or copper output, is measured in '00,000s of metric tons.
Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).
All specifications include indicator variables for female and for five-year age groups.
All specifications include controls for total output in all of Zambia, for the number of mines within 10km, and for the interactions with the female indicator variable.
All specifications include year fixed effects, month fixed effects, district fixed effects, and a linear time trend.
All specifications include interactions between the female indicator variable and number of mines with 10km and total output in all of Zambia.

Table 7: Heterogeneity by Age in Effect of Copper Boom on Sexual Behavior and In-Migration, 2001-2007

Dependent variable:	married	any partner	multiple partners	money	alcohol	proportion unprotected	sex in past month	pregnant	resident less than one year
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CU output, 0-10km	-0.026	0.036	-0.070	-0.032	-0.009	0.146	-0.198	-0.129	0.151
	(0.031)	(0.079)	(0.032)	(0.048)	(0.049)	(0.091)	(0.095)	(0.048)	(0.068)
Age 20-29 * CU output, 0-10km	-0.200	-0.239	-0.006	-0.078	-0.155	-0.169	0.018	0.052	0.062
	(0.080)	(0.082)	(0.052)	(0.057)	(0.068)	(0.094)	(0.105)	(0.064)	(0.069)
Age 30-39 * CU output, 0-10km	0.072	-0.082	0.035	-0.033	-0.131	-0.244	0.264	0.163	-0.037
	(0.050)	(0.088)	(0.084)	(0.056)	(0.082)	(0.091)	(0.121)	(0.065)	(0.087)
Age 40-49 * CU output, 0-10km	-0.077	-0.020	0.069	0.017	-0.159	-0.276	0.162	0.075	-0.047
	(0.080)	(0.122)	(0.060)	(0.066)	(0.096)	(0.138)	(0.134)	(0.055)	(0.137)
Age 50-59 * CU output, 0-10km	0.027	-0.010	-0.051	-0.016	-0.119	-0.131	0.051		0.022
	(0.047)	(0.114)	(0.077)	(0.051)	(0.129)	(0.093)	(0.134)		(0.160)
Female * CU output, 0-10km	-0.097	-0.052	0.021	-0.008	-0.034	-0.341	0.020		0.017
	(0.042)	(0.081)	(0.042)	(0.072)	(0.046)	(0.147)	(0.143)		(0.081)
Female * Age 20-29 * CU output, 0-10km	0.270	0.195	0.027	0.070	0.210	0.356	0.198		-0.131
	(0.105)	(0.111)	(0.058)	(0.083)	(0.100)	(0.159)	(0.175)		(0.097)
Female * Age 30-39 * CU output, 0-10km	0.121	0.145	-0.032	0.063	0.216	0.401	0.042		-0.062
	(0.075)	(0.090)	(0.086)	(0.092)	(0.071)	(0.151)	(0.193)		(0.102)
Female * Age 40-49 * CU output, 0-10km	0.074	0.027	-0.048	0.030	0.223	0.534	-0.169		0.049
	(0.129)	(0.134)	(0.067)	(0.094)	(0.150)	(0.192)	(0.210)		(0.129)
Observations	25,171	25,171	25,171	16,301	21,501	18,646	21,831	12,953	25,135

Notes: Data come from the 2001 and 2007 DHS survey rounds and the 2003 and 2005 ZSBS survey rounds.
Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).
CU output, or copper output, is measured in '00,000s of metric tons.
All specifications include indicator variables for gender and for five-year age groups,.
All specifications include controls for total output in all of Zambia, for the number of mines within 10km, as well as controls for the number of mines within 10km (and total copper output in all of Zambia) interacted with the age-group indicators, female indicator, and the interactions thereof.
Excluded age category is Age 15-19.
All specifications include year fixed effects, month fixed effects, district fixed effects, and a linear time trend.

Table 8: Mean Characteristics of Migrants and Non-Migrants in Mining Areas, 2001-2007

	mining cities	
	non-migrants	migrants
	(1)	(2)
Consumer durables		
Floor	0.77	0.78
Refrigerator	0.32	0.33
Television	0.56	0.56
Radio	0.69	0.70
Car	0.06	0.06
Motorcycle	0.00	0.00
Bicycle	0.31	0.24
Sexual behavior		
Married	0.49	0.44
Any partner	0.69	0.70
Multiple partners	0.07	0.07
Money exchanged	0.05	0.03
Alcohol use at sex	0.17	0.15
Proportion unprotected sex	0.85	0.78
Sex in past month	0.57	0.50
Pregnant	0.24	0.35
Demographic characteristics		
Female	0.50	0.56
Age	29.6	25.8
Health		
HIV positive	0.155	0.148

Notes: Data come from the 2001 and 2007 DHS survey rounds and the 2003 and 2005 ZSBS survey rounds.
Non-migrants defined as respondents residing in the same household for at least five years.
Migrants defined as respondents residing in the same household for less than twelve months.

Table 9: Effect of Copper Boom on Household Consumer Durable Ownership for Non-Migrants, 2001-2007

Dependent variable:	floor	refrigerator	television	radio	car	motorcycle	bicycle
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Sample restricted to individuals resident in same household for at least five years							
CU output, 0-10km	0.373	0.274	0.366	0.127	0.037	-0.003	-0.043
	(0.138)	(0.120)	(0.141)	(0.091)	(0.039)	(0.002)	(0.088)
Observations	16,557	16,598	16,606	16,630	16,593	16,595	16,607
Panel B: Sample restricted to individuals resident in same household for at least one year							
CU output, 0-10km	0.324	0.259	0.366	0.129	0.044	-0.003	-0.042
	(0.146)	(0.112)	(0.136)	(0.083)	(0.034)	(0.002)	(0.096)
Observations	20,675	20,743	20,750	20,778	20,735	20,737	20,751

Notes: Data come from the 2001 and 2007 DHS survey rounds and the 2003 and 2005 ZSBS survey rounds.
CU output, or copper output, is measured in '00,000s of metric tons.
Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).
All specifications include indicator variables for female and for five-year age groups.
All specifications include controls for total copper output in all of Zambia and for the number of mines within 10km.
All specifications include year fixed effects, month fixed effects, district fixed effects, and a linear time trend.

Table 10: Effect of Copper Boom on Sexual Behavior of Non-Migrants, 2001-2007

Dependent variable:	married	any partner	multiple partners	money	alcohol	proportion unprotected	sex in past month	pregnant
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Sample restricted to individuals resident in same household for at least five years								
CU output, 0-10km	-0.043	-0.004	-0.038	-0.045	-0.025	-0.005	-0.080	-0.010
	(0.040)	(0.035)	(0.028)	(0.029)	(0.033)	(0.046)	(0.051)	(0.050)
Observations	16,656	16,656	16,656	11,263	14,241	12,359	14,415	8,084
Panel B: Sample restricted to individuals resident in same household for at least one year								
CU output, 0-10km	-0.068	-0.036	-0.041	-0.044	-0.044	-0.015	-0.058	-0.091
	(0.034)	(0.033)	(0.027)	(0.027)	(0.031)	(0.044)	(0.037)	(0.041)
Observations	20,811	20,811	20,811	13,876	17,778	15,474	18,053	10,384

Notes: Data come from the 2001 and 2007 DHS survey rounds and the 2003 and 2005 ZSBS survey rounds.
CU output, or copper output, is measured in '00,000s of metric tons.
Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).
All specifications include indicator variables for female and for five-year age groups.
All specifications include controls for total copper output in all of Zambia and for the number of mines within 10km.
All specifications include year fixed effects, month fixed effects, district fixed effects, and a linear time trend.