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The socioeconomic impact of coal mining in Mozambique

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Abstract: This study assesses the impact of four coal mines in Mozambique on the socioeconomic outcomes of the local population. We combine four waves of household surveys with coal mine locations data and employ a difference-in-difference model. The timing of the surveys allows us to control for pre-trends and to differentiate between the effects during the investment and production periods. The mines led to an increase in consumption and a decline in poverty, because of workers moving out of agriculture into higher-paid jobs in the mining and service sectors. This effect is especially strong for women, who gained wage jobs and reduced unpaid family work. Access to basic services, such as drinking water, electricity, and health services, improved. Primary education completion rates increased, while children's schooling was unaffected. Negative consequences were found related to the incidence of sickness and a decline in market access, which may be related to resettling programmes.

Key words: mining, coal mines, difference-in-difference, poverty, Mozambique

JEL classification: L72, O12, O13, Q32

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1 Introduction

Mozambique's Tete province is rich in coal. Although the existence of this resource wealth was known for many years, it took until 2011 for large-scale production to start. Since 2011, four mines have become active, reaching a production level of 15.2 million tons[1] in 2018 most of which are exported (TA 2019). Within seven years, the coal sector became the biggest contributor to Mozambique's export earnings, contributing US$1.75 billion (around 33 per cent) in 2018 (BdM 2021), making Mozambique the tenth largest coal exporter in the world (EIA 2020a). Furthermore, proven coal reserves in Mozambique are estimated at 38.4 billion tons and it is this vast amount of untapped coal which provides the country with the potential to open up many more mines (EITI 2020). This opens the question of what an active mine means for the local population, i.e. what is the local socioeconomic impact of coal mining in Mozambique?

Mining should have positive effects on the local population. First, the additional economic activity increases employment opportunities directly, by employing labour in the mine, and indirectly, by increasing demand for other goods from the nearby agricultural and service sectors. Second, mine operators pay taxes and royalties. In many cases, some of the income is distributed to the local community and can be used to improve public goods provision such as hospitals, schools, and roads. Third, mine operators are often obliged to provide local content in the form of financing schools or other public goods, which, by definition, are supposed to benefit the local communities. Fourth, mines often require infrastructure in the form of roads, electricity, or water supply from which nearby communities can benefit as well.

However, coal mines have potentially detrimental effects for the livelihoods of people nearby. First, mining is often associated with environmental hazards like air and water pollution. Second, there can be similar effects at the local level to those in the resource curse theory, which predicts the deterioration of national institutions through corruption and elite capture. Mine operators may be incentivized to bribe local leaders to avoid higher costs stemming from environmental regulations, local content provision, or labour laws. Third, in many situations, including in Mozambique, the valuable minerals are found in regions where people previously settled. This requires the resettlement of local communities, which often comes with promises of new houses and infrastructure in another location but is not always followed through, leaving the local population dislocated and worse off.

The direction and magnitude of the socioeconomic impact of coal mining is therefore an empirical question. This paper aims to contribute to the debate on the impact of mining by analysing the local socioeconomic impact of coal mining in Mozambique. It shows how the four coal mines that have opened in Mozambique since 2011 have influenced the population living in a mining *posto administrativo* (PA)[2] and estimates whether the mines have had a predominantly positive or negative impact on the lives of the local population. We combine a rich individual-level dataset with geocoded information about coal mining and apply a difference-in-difference specification to disentangle the investment and production impacts of an active mine on the local population. Outcomes of interest include income, poverty, employment, access to basic services, education, and health.

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[1] 8.3 million tons of coke coal and 6.9 million tons of thermal coal (TA 2019).

[2] *Postos Administrativos* are the third sub-national administrative unit after provinces and districts.

We find that the opening of the coal mines has led to an increase in consumption and a decline in poverty, which can be explained by the movement of workers out of agriculture and into the mining and services sectors. The employment effects are especially strong for women, who gain wage jobs and reduce unpaid family work. Access to basic services, such as drinking water, electricity, and health services, has improved. Primary education completion rates have increased, while young children's schooling has been unaffected. Negative consequences of the coal mine opening are identified in terms of the incidence of sickness and a decline in market access during the investment period, which may be related to resettlement of some of the population.

Much of the literature on natural resources is focused on the macroeconomic effects, but a growing literature is now also concerned with the local effects (see, for example, Aragón et al. 2015; Aragón and Rud 2013; Axbard et al. 2016; Benshaul-Tolonen 2019b; Benshaul-Tolonen et al. 2019; Caselli and Michaels 2013; Kotsadam and Tolonen 2016; Loayza et al. 2013; von der Goltz and Barnwal 2019; Wilson 2012). Aragón et al. (2015) provided a comprehensive summary of the theory and empirical literature on the local impact of natural resources. They noted several shortcomings in the status quo of the current literature, which partly guided our paper. First, most of the evidence focuses on developed countries such as the USA, Australia, or Canada. Little evidence exists for less-developed countries. Second, they commented that the focus of the literature is on economic indicators, with less importance given to social indicators such as health or education.

More recently, a few studies have emerged to which our paper most closely relates. For example, von der Goltz and Barnwal (2019) analysed the trade-off of living close to a mine by estimating the economic benefits and health costs. In their sample of 800 mines in 44 developing countries, they found that proximity to an active mine increased households' asset wealth by 0.3 standard deviations, but anaemia among women and stunting in children increased by 10 and 5 per cent, respectively. Benshaul-Tolonen et al. (2019) analysed the impact of gold mines in Ghana. They found that men living close to an active mine were more likely to benefit directly from employment as miners than men living further away and that women living close to a mine benefited through indirect employment opportunities and cash for work earnings. In contrast to von der Goltz and Barnwal (2019), they found an infant mortality-decreasing effect due to mining activity in their sample. In another paper, Kotsadam and Tolonen (2016) analysed the impact of large-scale mining throughout Africa with a focus on heterogeneity by gender. They found that mining triggered a local structural change, shifting women from agriculture to the services sector, while at the same time overall female employment decreased. Men, on the other side, moved into skilled manual labour and mining.

This paper contributes to the literature on the local impact of mining in several ways. It is the first to conduct a thorough quantitative analysis of the socioeconomic impact of coal mining in Mozambique. Coal mining in Mozambique represents an interesting case study for itself and for other countries. While the studies referred to above mostly include countries with centuries of mining experience (e.g. Ghana or Peru), Mozambique has only recently started to extract its rich natural resources and may therefore lack the institutions and capacity to regulate the extractive industry such that it benefits the population. The results may therefore be informative for other countries that are yet to start extracting their natural resources. Furthermore, this is the first study to our knowledge that includes all the outcomes mentioned in the studies above—economic, public service, health, and education—in one study and that differentiates the impact between the investment and the production phase of a mine. Additionally, the results are interesting for Mozambique because there are many more natural resources to extract in the country. Mozambique has an estimated 38.4 billion tons of untapped coal reserves, which provides the possibility of opening many more mines. Further, mainly untapped, natural resources in Mozambique include graphite, iron ore, titanium, apatite, marble, bentonite, bauxite, kaolin, copper, gold, rubies, and tantalum (EITI 2020). In addition to the mines, Mozambique has discovered an immense gas deposit in the Rovuma Basin with an estimated 165 TcF of natural gas (EIA 2020b). The resources sector will play a leading role in determining the country's future development trajectory and this study offers insights on its potential contribution to local socioeconomic development.

The paper proceeds as follows. Section 2 provides an overview of Mozambique's coal mining industry. Section 3 describes the methodology, identification strategy, and data used to analyse the local impact of coal mines in Mozambique. Sections 4 and 5 present the results and robustness checks. Section 6 concludes and discusses the policy implications of the findings for Mozambique and other resource-rich countries.

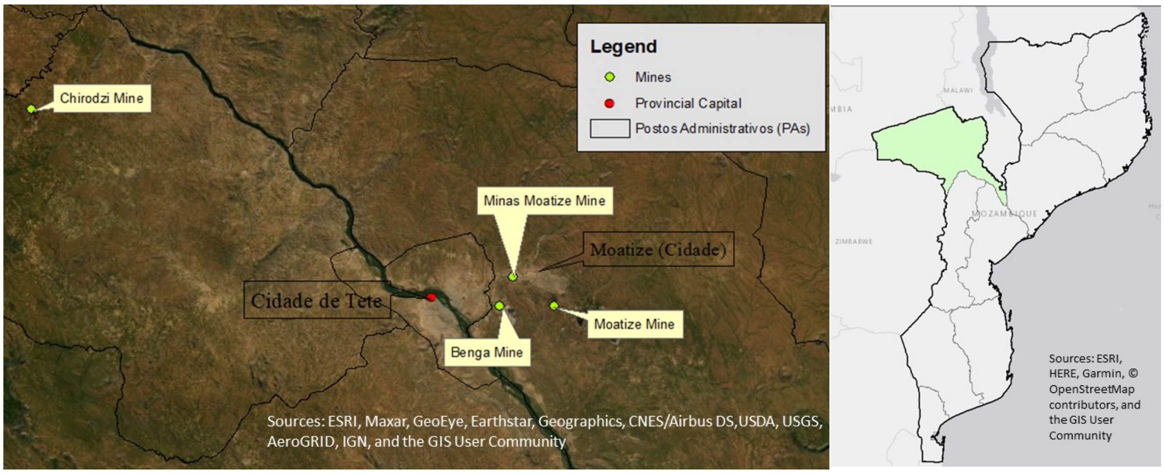
2 The coal sector in Mozambique

Geological records of coal deposits in Mozambique's Tete province were first recorded back in 1859 by Richard Thorton. Even so, locals were using coal well before Thornton's study. Most of the coal is located within the Ecca rock formation, of the Karoo Supergroup, in the Zambezi graben of Tete province. The coalfield is considered to be the largest undeveloped coal area in the world (Hatton and Fardell 2012). Currently, the Ministry of Mineral Resources and Energy (MIREME) estimates coal reserves at 38.4 billion tons (EITI 2020).

The first minor coal mining operation in the country took place during the colonial era, but this operation was not relevant to the country's economy (de Matos and Medeiros 2012). During the post-war period, coal production remained far below capacity due to the destruction of the main railroad linking the Moatize district to the port of Beira. Despite this obstacle, the state-owned company Carbomoc carried out coal extraction in small quantities, which were mainly exported to Malawi (Yager 2001).

The first interests in coal on an industrial scale were expressed in the mid-90s by Brazil's Company Vale do Rio Doce (Vale) after a feasibility study had determined that the Moatize-Minjov reserves were adequate to support a long-term annual coal output of 22 Mmt (Michalski 1995). Despite the enormous potential, industrial-scale coal exploration only started in 2011, by Vale, at the Moatize-1 mine. In 2012, Rio Tinto plc followed and started exploration in the Benga Mine (which is adjacent to the Moatize mine). Two more mines started production in 2012: the Chirodzi project, operated by Jindal Steel & Power Ltd in western Tete, and the Minas Moatize mine, operated by Beacon Hill Resources plc. The four coal mines are located in the districts of Moatize and Marara; both districts are adjacent to the provincial capital city of Tete. All four mines use open-pit technology to extract coal (Yager 2015, 2019). Figure 1 and Table 1 show the location and the year that production started for the four mines.

Figure 1: Coal mine locations in Tete province, Mozambique



Source: authors' representation using ArcGIS, based on information from coal mine locations.

Table 1: Coal mines in Mozambique

Mine name	Mine operator	Production started	District
Moatize mine	Vale	2011	Moatize
Benga mine	Rio Tinto[3]	2012	Moatize
Chirodzi mine	Jindal Steel & Power	2012	Marara[4]
Minas Moatize mine	Beacon Hill Res.	2012	Moatize

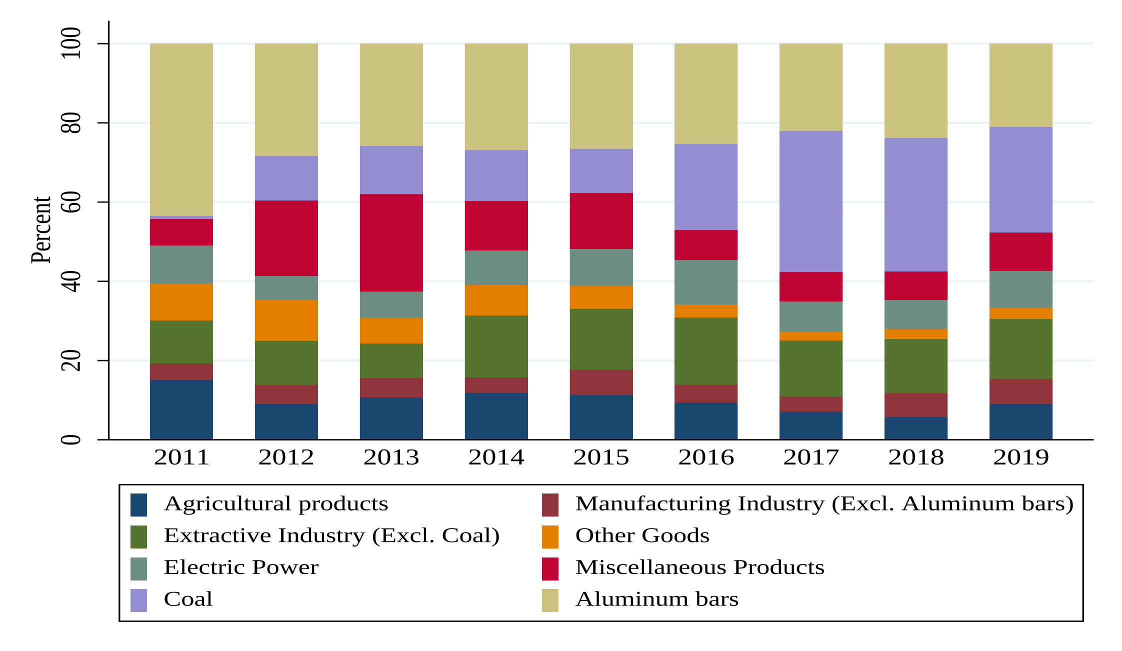
Source: authors' elaboration based on data from USGS (2020).

A major obstacle for coal exploration in Mozambique is the lack of infrastructure. The coal deposits are located in the most western province of the country, Tete, and any proceeds have to be transported by rail across the country to the ports in Beira or Nacala. The capacity of the railway lines represents the bottleneck in the supply chain and determines the amount of coal that is exported (Yager 2010, 2015). Despite the railway constraint, the coal sector revealed itself to be one of the most important export sectors for Mozambique's economy. Just two years after production started, coal became the country's second most-exported product. By 2017, it overtook aluminium and became the most important contributor to export earnings (see Figure 2).

[3] Rio Tinto sold its 65 per cent share to IVCL.

[4] Formerly part of Changara district.

Figure 2: Mozambique's export earnings composition 2011–19



Source: authors' representation based on data from BdM (2021).

The coal sector initially contributed very little to the state budget because the mining companies enjoyed beneficial tax treatments until 2015 as stipulated in Law 4/2009 of 12 January. With the approval of Law 20/2014 of 18 August, the government implemented some changes to the status quo. First, the coal sector's contribution to the state budget increased from almost zero in 2014 and the years before to 10,306 million meticais or about 4.8 per cent of the total state budget in 2017 (TA 2018, 2019). And. second, the law requires, in article 20, that a certain percentage, fixed by the state budget law (currently 2.75 per cent), be transferred to communities in the localities where the projects are located.

Large-scale mining projects often require the displacement of people from their lands and homes. The coalmines in Tete were no exception. During the installation period, the coal projects made it necessary to resettle 2,528 families (1,365 families by Vale, 484 families by Jindal, and 679 families by IVCL/Rio Tinto) (HRW 2013). The outcome of a resettlement programme depends heavily on the parties involved and their willingness to compromise. Unfortunately, more often than not, resettlement programmes have a negative impact on the lives of the people and Mozambique is no exception. Wiegink (2020) reported that the new settlements did not provide the promised infrastructure. For example, the water supply was insecure in the new settlements, the distance to the market in Moatize increased for resettled people, public transportation became inadequate, and the agricultural land provided was of low quality. Because of these problems, the resettlement process was not entirely peaceful and was characterized by much controversy due to the conflicts that ensued, including violent repression by the state's security forces (HRW 2013).

3 Methodology and data

3.1 Data

Information on individual and household outcomes is taken from the national household consumption surveys (*Inquéritos aos Agregados Familiares sobre Orçamento Familiar* (IAF) 1996/97 and 2002/03 and the *Inquéritos sobre Orçamento Familiar* (IOF) 2008/09 and 2014/15 (INE 1997, 2004, 2010, 2015)). These surveys collect detailed information on demographics, education, employment, health, and consumption and serve as the baseline for the national poverty assessments which calculate national poverty lines. While the data are repeated across sections, we can match the sub-national administrative units (*posto administrativo* (PAs)) over time. PAs are the third sub-national administrative unit after provinces and districts. To give an idea of the size of these units, the 2007 Census data documents 431 PAs in the country and shows that, on average, around 47,000 people live in a PA.

From the individual and household data, we define four sets of outcome variables and some control variables. The complete list of all variables, their definitions, and summary statistics are documented in Tables A1 and A2 in the Appendix. The first group of outcomes are economic measures of consumption and poverty. We include *real daily per capita consumption* deflated by the national poverty line, a dummy for whether someone is *poor* according to the national poverty line, *the poverty gap*, and the *squared poverty gap* to investigate improvements in terms of poverty depth. This is especially relevant for Mozambique, which is one of the poorest countries in the world and where, although it experienced a significant reduction in poverty during our study period, poverty levels remain high. The second group of outcomes looks at structural change in the form of employment by sector (*agriculture*, *manufacturing*, *mining*, *government*, and *services*) and employment type (*self-employed*, *wage work*, *family work*, and *domestic work*). Third, we consider improvements in infrastructure or access to basic public services, measured by access to *electricity* and time it takes to go to the *nearest water source*, *market*, or *transport* stop. Lastly, health (*sick* and *seeking health care*) and education (*primary* and *absent*) are considered to capture the social dimensions of well-being. We further include the *age* and *education* of individuals as control variables.

Table 2: Pre-treatment summary statistics

	Treated	Control	Diff.	t-stats
Log of per capita exp.	-0.41	-0.17	0.24***	7.96
Poor	0.70	0.64	-0.07***	-3.21
Poverty gap	34.86	24.91	-9.95***	-8.70
Squared poverty gap	21.33	12.73	-8.60***	-10.90
Working	0.59	0.58	-0.01	-0.43
Agriculture	0.70	0.79	0.09***	3.70
Construction	0.01	0.01	0.01	1.05
Mining	0.00	0.01	0.01*	1.65
Government	0.05	0.02	-0.02**	-2.22
Manufacturing	0.00	0.01	0.01	1.17
Services	0.04	0.07	0.02	1.53
Self-employed	0.41	0.44	0.03	1.13
Wage work	0.10	0.08	-0.02	-1.19
Domestic	0.01	0.01	-0.00	-0.28
Family work	0.28	0.38	0.11***	3.58
Walking time to water	1.33	1.35	0.03	0.69
Walking time to market	2.22	1.69	-0.53***	-6.85
Walking time to transp.	2.32	1.79	-0.53***	-6.44
Electricity	0.06	0.02	-0.04***	-5.23
Sick	0.13	0.14	0.01	0.58
Seeking health service	0.64	0.66	0.02	0.41
Absent	0.22	0.27	0.05	1.20
Primary	0.04	0.05	0.00	0.16
Female	0.51	0.48	-0.03	-1.35

Age	20.67	22.12	1.45*	1.77

Note: ***0.01, **0.05, *0.1 are significance levels of t-test mean comparison between the treated and the control group using pre-treatment (IOF96/97 and IOF02/03) data.

Source: authors' estimation based on IAF/IOF data.

Table 2 compares the means of the outcome and control variables between the treatment and the control groups before mining started (IOF96/97 and IOF02/03). The table shows that there are various pre-treatment differences among both groups. Individuals in the treatment group have higher *per capita consumption* and are slightly less likely to be *poor*. For both groups, most individuals are employed in *agriculture*, with the control group having a significantly bigger share compared to the treatment group. In terms of access to public services, people in the control group spend significantly more time walking to the closest source of *water*, *market*, and *transportation*. Finally, individuals in the treatment group are younger.

Due to our difference-in-difference estimation approach, the only information required about the mines is the dates of the final investment decision and the production start. Both dates were extracted from the International Minerals Statistics about Mozambique from the US Geology Survey (USGS 2020).

3.2 Individual-level difference-in-difference

The aim of this paper is to estimate the socioeconomic impact of an operating mine on the local population using the case of large coal mines in Mozambique. To do so, we apply a standard difference-in-difference method of the following form:

$$Y_{ipt} = \beta_0 + \beta_1\, Treat_p + \beta_2\, Inv_t + \beta_3\, Prod_t + \delta_1\, Inv_t\, x\, Treat_p + \delta_2\, Prod_t\, x\, Treat_p + \lambda X_{it} + D_d + \gamma_t + \varepsilon_{ipt} \quad (1)$$

where Y_{ipt} is the outcome variable measuring consumption, poverty, employment, education, or a health indicator of individual i in PA p in year t. Instead of the classic two-period difference-in-difference (pre- and post-treatment periods), we divide the post-treatment period further into two phases: the investment period (Inv_t), which covers the time a mining company needs to make its mine operational,[5] and the production period ($Prod_t$), which covers the period in which the mine produces coal. $Treat_p$ is a dummy which indicates whether a mine is located in a PA p or not. We will discuss this definition in more detail below. The parameters of interest are δ_1 and δ_2, the two coefficients of the interaction terms of $Treat_p$ with $Prod_t$ and Inv_t. They estimate the effect of the coal mine investment and production periods respectively on the socioeconomic outcomes of an individual living in a mining PA. X_{it} includes control variables which measure individual specific characteristics, such as years of education, age, and in which quarter of the year the individual was interviewed, to control for seasonality in the outcomes. D_d and γ_t are district and time fixed effects which control for time-invariant unobservable characteristics at the district level and for shocks affecting all individuals in a specific year. The choice of district fixed effects instead of PA fixed effects is derived from the fact that relevant institutions and regulations are applied at the district level.

Using dummies instead of production quantity might be seen as a suboptimal choice because additional variation stemming from production level is not exploited. However, exploiting the

[5] We define the start year of the investment period as the year in which the final investment decision (FID) was made and the end year as the year in which production started.

variation in production comes with the risk of measurement error if the mining companies misreported the quantity. Furthermore, information about the individual is only available in the survey years, which makes it difficult to associate short-term production changes with the corresponding survey in which the effect occurs.

Benshaul-Tolonen (2019a) and Benshaul-Tolonen et al. (2019) showed that the effect of a mine can be heterogeneous between men and women. To explore this form of heterogeneity, we run all specifications separately by sex.

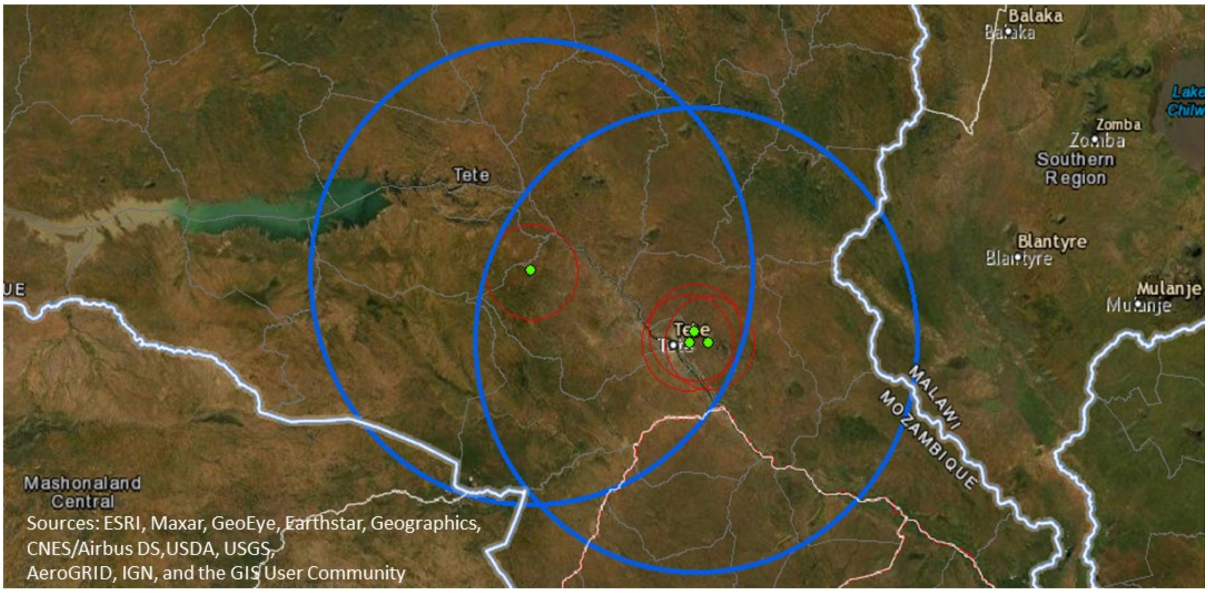
3.3 Identifying assumptions

There are two important aspects for our identification to work: 1) treatment should be exogenous; and 2) the choice of the control group should be valid. With regard to the first point, from the data at hand, we cannot show that the opening of the coal mines was strictly exogenous. Therefore, we first rely here on the assumptions made in earlier studies that the timing of opening a mine is not related to socioeconomic variables of the local population and therefore can be treated as exogenous (see, e.g. Aragón et al. 2015; Benshaul-Tolonen 2019b; Benshaul-Tolonen et al. 2019; Kotsadam and Tolonen 2016; von der Goltz and Barnwal 2019). Second, instead of using the opening of a mine as the only treatment, we differentiate between the investment and production periods, allowing both to be the treatment. This way changes the outcomes because the preparations triggered before the actual coal production are captured in the investment effect. In other words, as the literature accepts the opening of a mine as exogenous, it should be even easier to accept that the FID is exogenous because the FID happens earlier, and its timing should be even more unpredictable.

Regarding the choice of the control group, one would ideally like to estimate the effect of a treatment on the treated as the difference between the outcome after treatment and the outcome if the same population had not been treated. The challenge is that we cannot observe the latter counterfactual outcome. Thus, the difference-in-difference strategy allows us to get an estimate of the average treatment effect by comparing the treated and control groups before and after the treatment. This simple double difference is unbiased if two assumptions hold. The first assumption is that there are no time-invariant, area-specific unobservable characteristics that could change outcomes in the mining area but are unrelated to the mine opening itself. The second is that treatment is the same for all units, meaning that the trend in the outcome for treated and control units would also be the same in the absence of the treatment. In our application, the first assumption can be ensured by including district fixed effects. The second assumption cannot be directly tested but can be approximated by testing for a parallel trend in outcomes before the treatment. We thus exploit the full data available to us to regress the outcome on the treatment status (PA with a mine or not) in the two periods prior to the coal mine investment period.

The parallel trend assumption is unlikely to hold if the comparison group is fundamentally different from the treatment group prior to treatment. The coal mines in Mozambique are all located close to each other and close to the capital of Tete province; more specifically, they are located in the neighbouring PAs (see Figure 3). Thus, defining the control group as proposed in Kotsadam and Tolonen (2016), Benshaul-Tolonen et al. (2019), or von der Goltz and Barnwal (2019), i.e. by choosing a distance cut-off, will not work in our context. For example, application of the strategy of Benshaul-Tolonen et al. (2019) in our context is shown in Figure 3. They defined the treatment group as people living close to a mine (20 km radius, red circles) and the control group as individuals living far away from a mine (between 20 and 100 km, between red and blue circles). If applying this identification in our context, we would compare people living in or close to the provincial capital Tete, as can be seen in Figure 3, to those living more remotely. Doing this would not only capture the effect of living close to a coal mine but would simultaneously compare people living in the provincial capital with people living in more rural areas and would falsely claim that the difference was purely driven by the opening of the mines. Therefore, in our specific context, distance to a mine is not a good definition for a valid comparison group.

Figure 3: Coal mine locations in Tete province

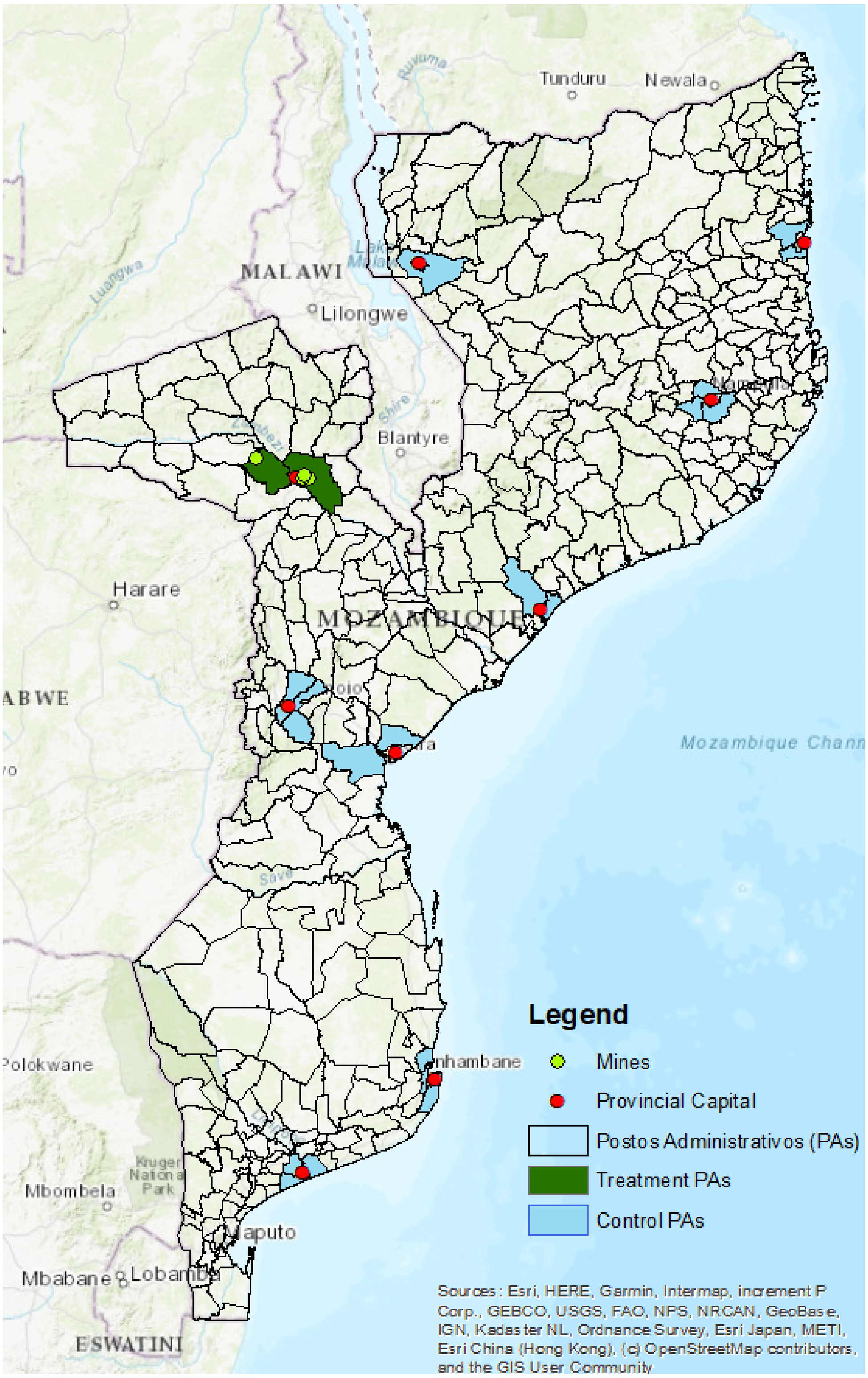


Note: green dots show the mines, red lines indicate a 20 km radius around the mines, blue lines indicate a 100 km radius around the mines (the 100 km radius for the Moatize, Benga, and Minas Moatize mines are combined to one radius with a minimum distance of 100 km to each mine).

Source: authors' elaboration using ArcGIS, based on location of coal mines.

Instead of distance, we use individuals living in PAs surrounding all 11 provincial capitals of the country as the control group. These individuals all benefit from proximity to a provincial capital and associated infrastructure, public services, and market size, but none experienced a coal mine opening during the study period. We exclude two capitals: the national capital Maputo City and Matola. Both areas are adjacent to each other and the richest in the country (DEEF 2016) and thus unlikely to present a feasible control group. Figure 4 shows the 22 PAs representing the control group (in blue) and the two treated PAs (in green).

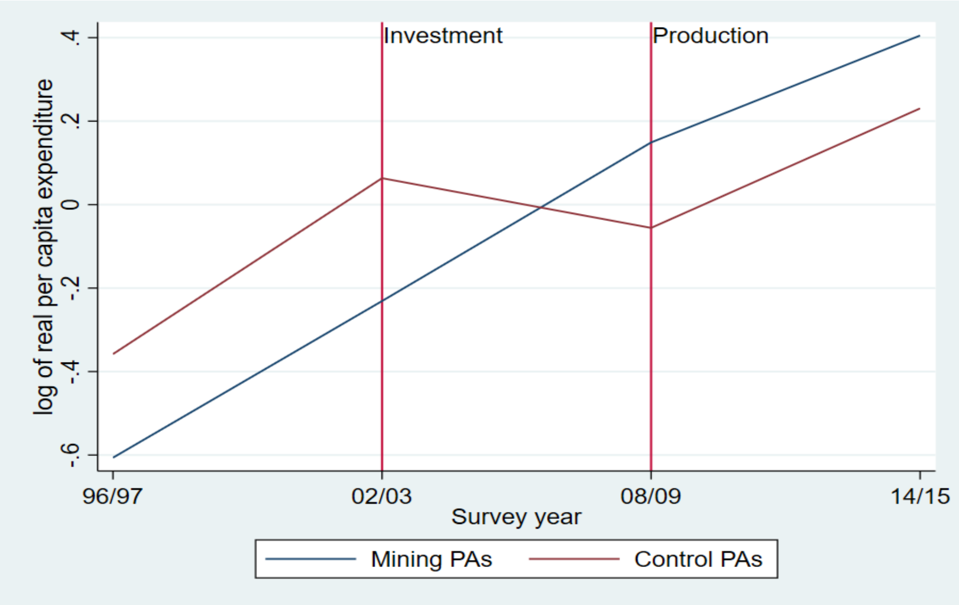
Figure 4: Map of mines, treatment, and control *postos administrativos*



Source: authors' elaboration using ArcGIS, based on location of coal mines and provincial capitals.

To see whether our choice of control group can be justified, we test the parallel trend assumption in the pre-treatment period for all our outcomes and report the result in each result table. As an example, Figure 5 shows the trends in *real per capita consumption* in the treated and control PAs before and during the investment and production periods. The pre-investment period shows that average consumption levels were higher in the control PAs than in the treated mining PAs, but they display a parallel upward trend, justifying our choice of control group. Furthermore, it seems that during the investment period, a small decline in consumption for the control group can be observed, while the consumption level for the treatment group continues to increase. From this naïve presentation it could be derived that between IAF02/03 and IOF08/09 the control group and most likely the rest of Mozambique suffered from the global financial crisis, which also affected food prices in Mozambique (Arndt et al. 2012; Arndt et al. 2015). At the same time, this negative effect was counteracted in the treatment group due to the investments undertaken to open the mines, allowing the treatment group to increase consumption above the control group levels.

Figure 5: Trend of real daily per capita consumption in treated and control *postos administrativos*



Source: authors' calculation based on IOF data.

4 Results

In this section, we present and discuss the results. Unless otherwise stated, the parallel trend assumption was confirmed by the graphical and regression test explained in Section 3.2. Hence, these results can be interpreted as the causal impact of living in a PA with an active coal mine. In the case of an invalid parallel trend test, we state it and interpret the results as correlation. Each table also indicates the validity of the parallel trend assumption for each specification with the words 'yes' (assumption confirmed), 'no' (assumption not confirmed), and 'n/a' (assumption could not be tested).[6]

The coefficients of interest in the tables are those of the interaction terms *Treat x Investment period* and *Treat x Production period*. The former shows the impact of living in a PA which is developing a mine, i.e. the impact of the initial investments needed to open a coalmine such as building the necessary infrastructure. The latter shows the impact of the operating mine on the dependent

[6] This is the case for the *walking time to market* and *walking time to transport station* variables because both variables were not included in the IAF96/97 and therefore only have one pre-treatment observation.

variable. Our applied difference-in-difference specification allows us to interpret the interaction term directly as the impact of the development and production of the mine.

4.1 Economic indicators

We start by showing the results for the economic indicators. Table 3 shows the impact of a coal mine on household consumption, the probability of being poor, the poverty gap, and the squared poverty gap for the full sample. All coefficients of the interaction terms (*Treat x investment period* and *Treat x production period*) are significant, indicating that the development and production of a mine affects consumption and poverty in the mining PA.

In theory, we would expect the development and operation of a mine to create new jobs and, regardless of the origin of the new employees, that they would receive a competitive or higher wage. Some of this income should lead to more demand for local goods and services and should therefore spill over to the local population. If the increase in consumption and some of the new jobs find their way to the poor, then poverty would also be expected to reduce as a result of the mine development and opening.

The results in Table 3 confirm this theory. Column 1 shows the impact of a mine on *per capita consumption*, which is positive and seems to be rather large. The significant coefficients of 0.444 and 0.395 indicate that consumption increased by 56 per cent and by 48 per cent in the development and the production periods, respectively.[7] In terms of monetary values this would equal an additional 3.6 MT or 3.1 MT per day.[8]

Table 3: Economic impact of a mine (full sample)

	(1) Log of per capita consumption	(2) Poor	(3) Poverty gap	(4) Squared poverty gap
Treat x Inv. period	0.444***	-0.208***	-21.23***	-15.70***
	(0.0492)	(0.0375)	(1.718)	(1.163)
Treat x Prod. period	0.395***	-0.116***	-13.21***	-10.50***
	(0.0456)	(0.0292)	(1.489)	(1.070)
Observations	12,608	12,608	12,608	12,608
R-squared	0.162	0.121	0.133	0.118
Controls	Yes	Yes	Yes	Yes
Parallel trend	Yes	Yes	Yes	Yes
Pre-treatment mean of the treated	-0.231	0.624	28.755	16.734

[7] The per capita consumption variable has been transformed by its natural logarithm; hence, the percentage change of living in a mining PA can be calculated as the exponential of the coefficient minus 1, e.g. exp(0.444)-1 = 0.558.

[8] Converting the percentage change into an absolute monetary value can be achieved in several steps. First, we calculate the mean of the treated in the period prior to the treatment (IAF02), which is -0.231. This is the logarithm of per capita consumption and exponentiation results in the per capita consumption mean of 0.793. As explained in Section 3.3, the per capita consumption variable has been deflated by the national poverty line to control for inflation. Therefore, we multiply the mean per capita consumption by the poverty line from the IAF02/03, which was 8,307. The mean per capita consumption of the treated in IAF02/03 therefore is 8,307 * 0.793 = 6,587. Increases of 55 per cent and 48 per cent are therefore equal to increases of 3,623 and 3,162, respectively. Note that these values are all stated in old meticais, and, therefore, to transform the value into current monetary values (new meticais), we divide them by 1,000.

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

Column 2 in Table 3 shows the impact of the investment and production phase of a mine on poverty. The *poor* dependent variable is a simple dummy which equals one if the individual's income is below the national poverty line, and zero otherwise. Hence, the model becomes a linear probability model, and the coefficients can be interpreted as a change in the probability of an individual being poor. The coefficients of interest—*treat × inv. period* and *treat × prod. period*—are both significant and negative, which is in line with the results in column 1 and shows that the income increase also benefited low-income individuals by pushing them above the poverty line.

Columns 3 and 4 in Table 3 show the impact of mine development and coal production on the *poverty gap* and the *squared poverty gap*. The *poverty gap* variable measures the distance of an individual from the poverty line and can be seen as a measure for the severity of poverty. The *squared poverty gap* does the same but gives more weight to those living further below the poverty line. Both coefficients of interest are significant and negative, i.e. the *poverty gap* and *squared poverty gap* reduced during mine development and coal production. The opening of the coal mine thus significantly benefited the very poor.

Benshaul-Tolonen (2019a) and Benshaul-Tolonen et al. (2019) showed that a mine can have a different impact on women and men. To exploit this potential source of heterogeneity, we further separate the sample into females and males. The results for the economic indicators, however, seem to show that there is no heterogeneity between the sexes (see Table A3 and Table A4 in the Appendix).

4.2 Structural change

In this section, we analyse how the development and opening of the mines has influenced the labour market in a mining PA. We would expect the mine to create new jobs, and, hence, employment to increase. However, it may also be the case that the new jobs are better paid, which the results in Table 3 confirm, and that the higher income of one family member could enable another family member to stay at home or continue with their education. Thus, the overall employment effect remains an empirical question.

Table 4 shows the impact of a mine on employment (*working*) for the full, female, and male samples. *Working* here is defined as a dummy equal to one if an individual stated they had worked in the past seven days or usually work for remuneration. While the economic indicators showed that income increased and poverty decreased, overall the number of people being employed declined during the development and the production periods. The results, therefore, indicate that the income increase of one family member could have been enough to allow another family member to stay at home or continue with their education. It is interesting to note here that the work-reducing effect of the mine is greater for the male sub-sample than for the female sub-sample. One possible explanation could be that relatively more young males chose to stay in school longer, which indicates that mines can have an impact on the perceived returns to education.

Table 4: Structural impact of a mine

	(1)	(2)	(3)
	Working (total)	Working (female)	Working (male)
Treat x Inv. period	-0.154***	-0.121***	-0.184***
	(0.0287)	(0.0400)	(0.0411)
Treat x Prod. period	-0.162***	-0.123***	-0.196***
	(0.0247)	(0.0362)	(0.0336)
Observations	11,947	5,611	6,335
R-squared	0.421	0.442	0.409
Controls	Yes	Yes	Yes
Parallel trend	Yes	Yes	Yes
Pre-treatment mean of the treated	0.523	0.520	0.527

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

To test whether the *working* reducing effect of a mine is affecting younger or older people more, we split the sample into young individuals (below 25 years) and older individuals (above 25) in Table A5 in the appendix. We can see that the effect is different in the investment period, that is, the effect is significant for young people but not significant for those above 25 years. During the production period, the results look rather similar for both samples. In terms of gender heterogeneity, we can see that the *working* reducing effect of a mine continues to be greater for males compared to females.

Next, we show the impact of a mine on employment for individual economic sectors. It should be noted that the parallel trend assumption could not be confirmed for the agriculture sector; therefore, the results here can only be interpreted as correlations, which is rather unfortunate considering the high importance of the agriculture sector as an employer in Mozambique.

Table 5 shows the results for the impact of mine development and production on the probability of working in a particular sector for the full sample. Overall, employment in *agriculture* reduced in the production period, *mining* increased in the development and production periods for obvious reasons, and employment in the *services sector* increased significantly in both periods. *Construction* and *manufacturing* were not affected and *government services* were only minimally affected in the investment period.

Table 5: Structural impact of a mine by sector (full sample)

	(1) Agric.	(2) Constr.	(3) Mining	(4) Govern.	(5) Manuf.	(6) Services
Treat x Inv. period	-0.0489	0.0178	0.0695***	-0.0412*	0.000659	0.0940**
	(0.0537)	(0.0168)	(0.0248)	(0.0220)	(0.0170)	(0.0393)
Treat x Prod. period	-0.180***	0.00830	0.0517***	0.0104	0.0151	0.200***
	(0.0409)	(0.00594)	(0.0164)	(0.0244)	(0.0199)	(0.0387)
Observations	6,100	6,100	6,100	6,100	6,100	6,100
R-squared	0.215	0.016	0.026	0.115	0.030	0.138
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Parallel trend	No	Yes	Yes	Yes	Yes	Yes
Pre-treatment mean of the treated	0.833	0.013	0.000	0.077	0.000	0.077

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

Table 6 shows the results for the female sub-sample. Overall, these results partly explain the reduction in *agriculture* and the increase in the *mining* and *services sectors* shown in Table 5. Female labour participation in the agricultural sector decreased significantly in the development and production periods. The opposite is true for *mining*, where female participation increased. It is surprising that it is women rather than men who are securing jobs in the mining sector (Table 7). Traditionally, it would be expected to be the other way around. However, it may be that the so-called 'male' work is done by foreigners with special skills from the country of origin of the operating company. At the same time, women may have secured other jobs in the offices of the international companies.

Table 6: Structural impact of a mine by sector (female sample)

	(1) Agric.	(2) Constr.	(3) Mining	(4) Govern.	(5) Manuf.	(6) Services
Treat x Inv. period	-0.171**	0.0372	0.112***	-0.0529	-0.00293	0.120*
	(0.0805)	(0.0313)	(0.0403)	(0.0360)	(0.0314)	(0.0624)
Treat x Prod. period	-0.143**	0.0204	0.0912***	-0.0414	0.0127	0.129**
	(0.0579)	(0.0130)	(0.0299)	(0.0338)	(0.0357)	(0.0571)
Observations	2,699	2,699	2,699	2,699	2,699	2,699
R-squared	0.261	0.034	0.048	0.103	0.058	0.144
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Parallel trend	No	Yes	Yes	Yes	Yes	Yes
Pre-treatment mean of the treated	0.722	0.025	0.000	0.114	0.000	0.139

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

Table 7 shows the results for the male sub-sample. Overall, it seems that male employment has been less or more slowly affected by the opening of the mines. During the investment period, no significant changes can be identified and, during the production period, we only find a decreasing effect for *agriculture* and an increasing effect for jobs in the *government* and *services sector*. It appears that the majority of men who leave agriculture move into the services sector.

Table 7: Structural impact of a mine by sector (male sample)

	(1) Agric.	(2) Constr.	(3) Mining	(4) Govern.	(5) Manuf.	(6) Services
Treat x Inv. period	0.0919	-0.00191	0.0237	-0.0238	-0.00167	0.0578
	(0.0589)	(0.00250)	(0.0236)	(0.0245)	(0.00302)	(0.0422)
Treat x Prod. period	-0.211***	0.00112	0.0122	0.0681*	0.0109	0.257***
	(0.0576)	(0.00131)	(0.0120)	(0.0350)	(0.0175)	(0.0527)
Observations	3,401	3,401	3,401	3,401	3,401	3,401
R-squared	0.194	0.009	0.024	0.146	0.016	0.152
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Parallel trend	No	Yes	Yes	Yes	Yes	No
Pre-treatment mean of the treated	0.948	0.000	0.000	0.039	0.000	0.013

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

In Table 8, we show the impact of a mine on the type of employment for the full, female, and male samples. We differentiate between *self-employed*, *wage work*, *domestic*, and unpaid *family work*. The full sample in panel A shows that *wage work* increased in the production phase and *domestic* work increased in the investment phase. Exploiting the heterogeneity between women and men reveals further insights. The male sub-sample shows no effect and confirms again that men move less and more slowly between jobs (panel C). Women, on the other hand, decreased *family work* in the investment phase and *self-employed* in the production phase. At the same time, women increased *domestic* work in the investment phase and mostly moved into *wage work* in both phases (panel B). This is in line with the results from Table 6. The decrease in *agriculture*, which is often considered as *self-employed* or unpaid *family work*, is compensated for by an increase in *wage work* and *domestic* work, which are most likely to be found in the mining and services sectors.

These results are in contrast to those of Benshaul-Tolonen (2019a) and Kotsadam and Tolonen (2016) who found strong employment effects for men. However, their results for women moving out of agricultural self-employment into services are comparable to ours.

Table 8: Structural impact of a mine by employment type (full sample)

	(1) Self-employed	(2) Wage work	(3) Domestic	(4) Family work
Panel A: full sample				
Treat x Inv. period	0.0593	0.0399	0.0339*	-0.0398
	(0.0598)	(0.0409)	(0.0200)	(0.0534)
Treat x Prod. period	-0.0427	0.0992***	0.00582	0.0510
	(0.0493)	(0.0359)	(0.0166)	(0.0379)
Observations	6,100	6,100	6,100	6,100
Parallel trend	Yes	Yes	Yes	No
Panel B: female sample				
Treat x Inv. period	0.00274	0.123*	0.0525*	-0.134***
	(0.0791)	(0.0683)	(0.0315)	(0.0472)
Treat x Prod. period	-0.144**	0.153***	0.00445	0.0710
Observations	2,699	2,699	2,699	2,699
Parallel trend	Yes	Yes	Yes	No
Panel C: male sample				
Treat x Inv. period	0.0891	-0.0533	0.0211	0.0910
	(0.0867)	(0.0356)	(0.0241)	(0.0860)
Treat x Prod. period	0.0838	0.0435	0.0101	0.00209
	(0.0656)	(0.0424)	(0.0214)	(0.0552)
Observations	3,401	3,401	3,401	3,401
Parallel trend	No	No	Yes	No

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

4.3 Public services

In this section, we discuss how mine development and coal production impact the access to public services by the people living in a mining PA. It should be noted that, for most of the specifications, the parallel trend assumption could not be tested (*walking time to market* and *transport station*) or was not valid (*electricity*). Therefore, the results should be interpreted with caution and only seen as correlation and not causation.

Given that the mines created higher consumption and attracted investment, we would expect public service provision also to have improved. This is because higher consumption and investment should lead to higher government income nationally as well as locally. Higher government income should be transferred to the people in the form of public goods. However, as the resource curse theory predicts, and provides evidence of at the national level, natural resources deteriorate institutions and promote corruption, leading to a waste of public funds (Bhattacharyya and Hodler 2010; Keller 2020; Robinson and Torvik 2005). The same can be the case at the local level.

To test whether a mine improves or deteriorates public goods we estimate in Table 9 the impact of a mine on a set of public goods proxies, namely *walking time to water*, *walking time to market*, *walking time to public transportation*, and *electricity*. *Walking time to water* and *electricity* decreased throughout the production period and this is also the case for *electricity* in the investment period. *Walking time to market* increased during the investment period. As markets are usually in a fixed location, it seems that this specification captured consequences of the resettlement programme and is in line with Wiegink's (2020) finding that the distance to the market in Moatize increased for resettled people.

Table 9: Impact of a mine on public services (full sample)

	(1) Walking time to water	(2) Walking time to market	(3) Walking time to transp.	(4) Electricity
Treat x Inv. period	-0.0630	0.433***	0.118	0.347***
	(0.0781)	(0.148)	(0.144)	(0.0305)
Treat x Prod. period	-0.103**	-0.200	0.0624	0.247***
	(0.0420)	(0.136)	(0.141)	(0.0187)
Observations	12,211	8,626	8,960	12,443
R-squared	0.136	0.130	0.200	0.479
Controls	Yes	Yes	Yes	Yes
Parallel trend	Yes	n/a	n/a	No
Pre-treatment mean of the treated	1.070	2.219	2.319	0.111

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

4.4 Health

Mining activities can directly influence the health of the people nearby by polluting the air or water, causing people to be sick more often. On the other hand, the mine creates higher consumption, which allows people to seek health care and provides the local government with funds that can be used to improve access to and provision of health care services.

The results in Table 10 show that both mechanisms are partly at play during the investment period but not during the production period. Columns 1, 3, and 5 show the impact of a mine on the likelihood of being *sick* for the full, female, and male samples. During the investment period, all interaction terms are significant except for the male sub-sample. During the same phase, all specifications show that both women and men were more likely to seek health services. The effect of an increase in *sick* and *seeking health service* reduces after the investment period. During the production period, the coefficients are insignificant. It is comforting not to observe an increase in the incidence of sickness during the actual coal production phase.

Table 10: Impact of a mine on health

	(1) Sick (total)	(2) Seeking health service (total)	(3) Sick (female)	(4) Seeking health service (female)	(5) Sick (male)	(6) Seeking health service (male)
Treat x Inv. period	0.0871***	0.258***	0.105**	0.304***	0.0693	0.231**
	(0.0297)	(0.0743)	(0.0418)	(0.110)	(0.0422)	(0.104)
Treat x Prod. period	-0.0180	0.0348	-0.0130	0.156	-0.0222	-0.0560
	(0.0207)	(0.0770)	(0.0292)	(0.113)	(0.0296)	(0.105)
Observations	12,573	1,732	5,919	745	6,653	987
R-squared	0.024	0.080	0.023	0.098	0.029	0.089
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Parallel trend	Yes	Yes	Yes	Yes	Yes	Yes
Pre-treatment mean of the treated	0.161	0.625	0.158	0.583	0.164	0.667

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

It would be interesting and policy relevant to further analyse whether the disappearance of the negative health effect during the production period is due to improved access to health services (people continue to be sick but are treated better) or the fact that environmental issues have been resolved (people become sick less often). In the former case, the health costs represent external costs because the polluter is not charged for them directly, which will be a burden on the public coffers. In the latter case, the costs are internalized, and the polluter has to carry them with pollution-reducing investments. Vale, for example, recognized that coal dust from its mine was a major environmental issue which negatively impacted the health of the local population and it therefore promised to invest in technology to reduce the impact (CoM 2020). Whether this is enough to eliminate the negative health impact or whether other regulations and incentives from the government are needed is an open question.

4.5 Education

As for the public services and health sectors, we would expect education to improve due to the opening of a mine. More funds should lead to more public services including education. Furthermore, with the documented income gains, families can allow their children to stay in school for longer instead of making them work.

Table 11 shows the results for the full, female, and male samples for the *absent* and *primary* variables. *Absent* measures that a school-aged child is currently not in school. While the situation for absenteeism does not change for any sample, the completion rate of primary education (*primary*) increased at least during the production period in all samples. *Primary* measures the probability of a person finishing at least primary education. This is a rough measure of educational attainment; however, it still shows that the population close to a mine became more educated because of the mine opening.

Table 11: Impact of a mine on education

	(1) Absent (total)	(2) Primary (total)	(1) Absent (female)	(2) Primary (female)	(1) Absent (male)	(2) Primary (male)
Treat x Inv. period	0.0339	0.0350	0.0169	0.0277	0.0595	0.0371
	(0.0372)	(0.0234)	(0.0511)	(0.0355)	(0.0564)	(0.0296)
Treat x Prod. period	0.0205	0.0875***	-0.00761	0.120***	0.0518	0.0634**
	(0.0379)	(0.0217)	(0.0535)	(0.0336)	(0.0542)	(0.0274)
Observations	3,142	12,611	1,510	5,947	1,632	6,663
R-squared	0.272	0.111	0.216	0.122	0.347	0.126
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Parallel trend	Yes	Yes	Yes	Yes	No	Yes
Pre-treatment mean of the treated	0.031	0.057	0.000	0.079	0.061	0.034

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, and age. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

The *primary* increasing effect may be driven by supply and/or demand factors. On the supply side, it may be that the local government invested in more teachers and school equipment, which increased the quality of education, leading to higher returns to schooling and making investment in education more lucrative. On the demand side, it may be that the higher incomes of households enabled family members to stay in school longer. Finally, the effect may also be driven by migration. Because of the mine, it may be that more educated people moved to Tete to benefit from the new employment possibilities and higher wages. The data does not allow us to control for migration but we will discuss the migration issue in the next section in full.

5 Robustness checks

We conduct two robustness checks and discuss the issue of migration in this section. We start with the migration issue because it is detrimental to understanding the results properly and continue with the first robustness check, which is concerned with the sensitivity of the control group. A further robustness check was conducted to test for different model specifications in terms of fixed effects.

5.1 Migration

A further point necessary to discuss here to understand our findings properly is migration. Unfortunately, our data does not include any information about the migration patterns of the individuals in our sample. This means that our results cannot be interpreted as the impact of a mine on an individual that lived in a mining PA before and after mining operation commenced. Our results show the impact of a mine on the total local population living in a mining PA. This means that some individuals in the sample did not necessarily live in the mining PA before the investment and/or production period and that other individuals only lived in the mining PA before the investment/production period but not afterwards.

From a methodological perspective, this could be interpreted as a migration bias if the migration patterns systematically influenced the results. However, from a policy perspective it could be argued that the results have validity on their own. A policy maker who has the choice to open a mine in their PA could be in favour of the mine if the mine attracts high-skilled/ high-paid mining labour whether it influences the current population or not.

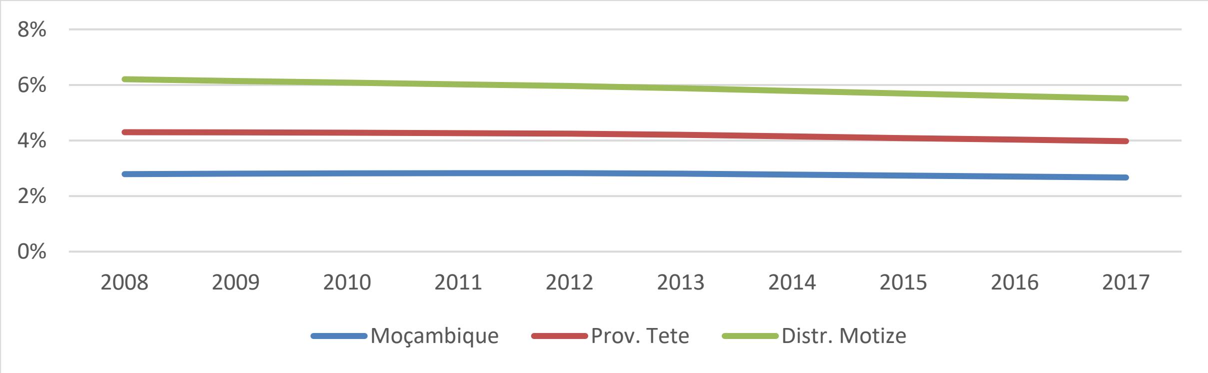
Our results, therefore, should be interpreted as the impact of a mine on the total population in the mining PA rather than the impact of a mine on an individual living in the mining PA for the full period. In this section, we treat the issue as a bias and discuss its potential direction.

First, we identify four potential channels which determine the direction of the migration bias. The first channel is that the opening of the mine attracts high-skilled labour. In this scenario, the new high-skilled labour would generate an upward bias to some of our results. For example, the positive consumption effect that we showed in Table 3 would be smaller because high-skilled labour is usually better paid than the average population, driving up the consumption variable after mining activities started. The second channel is that the mine pushes out high-skilled labour. This could be the case when the mining activities have detrimental health impacts on the population by polluting the air and water in the area. In this scenario, the consumption results would be biased downward because the high-skilled labourers who are also better paid would leave the mining PA to live in a healthier PA. The third channel is that the mine attracts low-skilled labour. The new economic activities in the mining PA could be seen as an opportunity, drawing people from other areas into the mining PA. In this scenario, the impact on the consumption variable would be a downward bias as low-skilled workers are usually paid less than the average. Therefore, the result would be greater than what is presented here. And, finally, the fourth channel is that the mine pushes out low-skilled labour. Considering that low-skilled workers with low wages do not have the means to move away from a polluted PA to a healthy PA, it could be argued that this channel could be ignored. However, this channel also includes re-settlement programmes which push the population away from the mine. In this scenario of low-skilled workers moving out of the mining PA, the results could be upward biased because people with lower consumption are no longer part of the mining PA sample after mining started.

It is likely that all four channels did occur during the sample period, which makes it difficult to determine whether or not the migration bias influences our results and in which direction the bias moves. Assuming that only channels one and three occurred would imply that the population in the mining PA increased, while the opposite would be true assuming that only channels two and four occurred. Figure 6 shows the population growth rate for Mozambique, Tete province, and the district of Moatize (INE 2020). Moatize, in which three of the four mines in our sample are located, does not show any big differences to the province and country trends.[9] This could mean that there was no change in the migration patterns, that channels one and three cancelled out channels two and four, or that the data does not show the migration change. Note that the data for Moatize is at the district level not the PA level and therefore migration between PAs in the same district cannot be observed.

[9] We are not able to show the growth rate for the Marara district, which is home to the Chirodzi mine, because the district was created in 2013 after an administrative reform and therefore no data pre-dating 2013 is available.

Figure 6: Population growth 2008–17



Source: author's representation using data from INE (2020).

In conclusion, we are not able to control for migration and can only repeat that our results do not show the impact of a local mine on an individual living in a mining PA. Rather, the results show the average impact on the total local population of the mining PA.

5.2 Sensitivity of the control group

Our decision to include PAs adjacent to provincial capitals is based on the locations of the mines, which are also in PAs adjacent to the provincial capital Tete. Given that there has been major development in the mining sector in Tete, it could also be argued that similar events may have happened in other provincial capitals. For example, if another resource project with similar attributes had started at the same time next to the city of Lichinga, then the inclusion of PAs adjacent to Lichinga would eventually bias our results downwards. Therefore, we conduct a sensitivity analysis which excludes one provincial capital at a time from the control group.

Another reason for conducting this sensitivity test is potential spillover effects. Geographically speaking, all 11 provincial capitals and their adjacent PAs are far enough away from each other to reduce the concerns of commuters who live in a control group PA but work in a treatment PA or vice versa. However, a potential spillover can still occur over distance, particularly given the direct rail link between Beira and Tete. This connection has been of significant importance because any investments from the mining companies were conditional on reviving this Sena railway line (Yager 2015, 2019). Therefore, any production in Tete influences the port of Beira. It is important to test whether the results change with or without Beira in the control group. It should be noted that if Beira influences the results, then it should be a downward bias and the real effect of the mine should be greater than what we estimate here.

Table A6 in the Appendix shows the results for this sensitivity test for the economic indicators (full sample).[10] The coefficients are stable and therefore the results are not driven by an individual provincial capital nor by geographic spillover effects

5.3 Different levels of fixed effects

The second robustness check is concerned with the level of fixed effects. The current choice of district fixed effects is based on the fact that any administrative decision and local investments are made at the district level. The literature recommends applying fixed effects in a double difference

[10] For reasons of space, we do not report the results for structural change, public service, health, and education outcomes. Those results can be requested from the authors.

estimation at the level of policy interference. Alternatively, we can control for fixed effects at the level of treatment, that is PAs or at the province level, which would, however, hide local heterogeneity. We feel strongly that the choice of district level fixed effects is the correct one in our setting. However, to be certain, we also test whether the results change with province and PA fixed effects.

The results for this robustness check are shown in Table A7 in the Appendix.[11] Overall, the results survive this robustness check and the coefficients do not change significantly regardless of the choice of fixed effects.

6 Conclusion

This paper estimated the local socioeconomic impact of mining on the population living in a mining PA in Mozambique. We combined a rich individual-level dataset with geocoded information about coal mines and applied a difference-in-difference specification allowing for heterogeneity in the impact of the investment and production periods.

The specification capturing the total effect of a mine revealed that the population living in a mining PA benefited from a significant gain in consumption and associated reduction in poverty. One channel of this result is the movements out of subsistence agriculture into the mining and service sector. It is notable that these results are stronger for women. In terms of non-economic impacts, we found that the opening of a coal mine may have improved access to basic services, including health services, and raised the educational attainment of the local population. Detrimental effects were identified for the incidence of sickness during the investment period, when market access also declined, possibly related to the associated resettlement of local inhabitants.

The results are mostly in line with previous studies which analyse the local impacts of mines. As this paper is one of the first to analyse the local socioeconomic impact of mining in a country with a short history of resource extraction, and as the results are broadly the same for longstanding resource producers, this shows that new resource producers should also learn from countries with a long history of resource extraction. However, the results which show a strong shift in women's employment, lower employment mobility for men, and improved access to services are new. This shows that there may be differences between new and longstanding resource producers which should be considered by policy makers. Furthermore, the negative effects on market access during the investment period highlight the need to ensure adequate resettlement procedures, monitoring, and compensation.

Analysing and monitoring the socioeconomic impact of mines should be a priority for policy makers because mismanagement of the resources can lead to f the population resenting the government and to protests, riots, and, in the most extreme cases, to conflict (Berman et al. 2017; Wiegink 2020). This is because mining activities comprise attributes which, in combination, differentiate them from other economic activities. First, the stakes are usually very high, as is the case in Mozambique, where coal mining quickly became the most important export item at the national level. Second, the geographic distribution of the natural resources is fixed, which forces the local population to be part of it whether they are asked to or not. Third, coal extraction requires capital and specialized skills that are often not present in the host country, which makes the

[11] For reasons of space, we do not report the results for structural change, public service, health, and education outcomes. Those results can be requested from the authors.

involvement of multinational companies necessary. Fourth, the duration of the resource projects often spans several decades, making today's decision making a bet against an uncertain future. And, most importantly, natural resources are not produced but are extracted. The fact that they are a product of nature and are geographically fixed raises important questions about their ownership and the resulting distribution of the gains. The many actors involved, in combination with uncertainty about the future, makes a static approach dangerous, often resulting in a status quo in which one or another actor is disadvantaged. Openness around renegotiations should be promoted and should be based on evidence. This paper aims to contribute to the evidence base on which such a discussion can take place.

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Appendix

Table A1: Variable names and definitions

Variable	Definition
Real per capita consumption	Daily real per capita consumption deflated by the national poverty line measured in meticais
Poor	Dummy equals one if consumption value is below the poverty line
Poverty gap	Mean distance between the consumption and the poverty line as a proportion of the poverty line
Poverty gap squared	Mean of the square of the (relative) poverty gap, considering only poor families
Working	Dummy equals one if the individual worked at least 1h in past week or has employment
Agriculture	Dummy equals one if the individual is employed in the agricultural sector
Construction	Dummy equals one if the individual is employed in the construction sector
Mining	Dummy equals one if the individual is employed in the mining sector
Government	Dummy equals one if the individual is employed in the government sector
Manufacturing	Dummy equals one if the individual is employed in the manufacturing sector
Services	Dummy equals one if the individual is employed in the service sector
Self-employed	Dummy equals one if the individual is self-employed
Wage work	Dummy equals one if the individual receives wage for work
Domestic	Dummy equals one if the individual works in a private house
Family work	Dummy equals one if the individual is a family worker without payment
Walking time to water	Walking time to the main water source measured in minutes
Walking time to market	Walking time to the nearest market measured in minutes
Walking time to transportation	Walking time to the nearest transport station measured in minutes
Electricity	Dummy equals one if the household uses electricity as the main source for illumination
Sick	Dummy equals one if the person was sick or suffered injury in the past two weeks
Seeking health service	Dummy equals one if the individual consulted a health worker or traditional healer in the past two weeks
Absent	Dummy equals one if a child of school age (6 to 13 years) was not attending school
Primary	Dummy equals one if the individual completed primary school
Age	Age measured in years

Source: authors' compilation based on IAF/IOF data.

Table A2: Summary statistics

	N	Mean	St.d.	Min	Max
Log of per capita consumption	12,611	-0.01	0.73	-2	4
Poor	12,611	0.53	0.50	0	1
Poverty gap	12,611	19.90	24.86	0	89
Squared poverty gap	12,611	10.14	16.37	0	79
Working	11,950	0.51	0.50	0	1
Agriculture	6,102	0.76	0.43	0	1
Construction	6,102	0.01	0.10	0	1
Mining	6,102	0.01	0.09	0	1
Government	6,102	0.03	0.18	0	1
Manufacturing	6,102	0.03	0.16	0	1
Services	6,102	0.12	0.32	0	1
Self-employed	6,102	0.47	0.50	0	1
Wage work	6,102	0.11	0.31	0	1
Domestic	6,102	0.02	0.13	0	1
Family work	6,102	0.36	0.48	0	1
Walking time to water	12,214	1.37	0.84	1	5
Walking time to market	8,627	1.92	1.35	1	5
Walking time to transportation	8,961	2.02	1.41	1	5
Electricity	12,447	0.26	0.44	0	1
Sick	12,576	0.14	0.34	0	1
Seeking health service	1,732	0.71	0.46	0	1
Absent	3,142	0.13	0.34	0	1
Primary	12,615	0.12	0.33	0	1
Female	12,613	0.47	0.50	0	1
Age	12,611	21.54	18.56	0	105

Source: authors’ calculation based on IAF/IOF data.

Table A3: Economic impact of a mine (female sample)

	(1) Log of per capita consumption	(2) Poor	(3) Poverty gap	(4) Poverty gap squared
Treat x Inv. period	0.439***	-0.167***	-22.08***	-16.98***
	(0.0702)	(0.0528)	(2.411)	(1.651)
Treat x Prod. period	0.408***	-0.101**	-14.31***	-11.74***
	(0.0676)	(0.0422)	(2.134)	(1.528)
Observations	5,947	5,947	5,947	5,947
R-squared	0.162	0.115	0.132	0.121
Controls	Yes	Yes	Yes	Yes
Parallel trend	Yes	Yes	Yes	No
Pre-treatment mean of the treated	-0.161	0.592	26.812	15.544

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

Table A4: Economic impact of a mine (male sample)

	(1) Log of per capita consumption	(2) Poor	(3) Poverty gap	(4) Poverty gap squared
Treat x Inv. period	0.451***	-0.249***	-20.30***	-14.36***
	(0.0692)	(0.0531)	(2.456)	(1.643)
Treat x Prod. period	0.381***	-0.130***	-12.04***	-9.213***
	(0.0616)	(0.0406)	(2.082)	(1.494)
Observations	6,660	6,660	6,660	6,660
R-squared	0.165	0.129	0.135	0.117
Controls	Yes	Yes	Yes	Yes
Parallel trend	No	No	No	Yes
Pre-treatment mean of the treated	-0.304	0.658	30.778	17.974

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

Table A5: Structural impact of a mine by age

	(1) Working (youth, total)	(2) Working (youth, female)	(3) Working (youth, male)	(4) Working (adult, total)	(5) Working (adult, female)	(6) Working (adult, male)
Treat x Inv. period	-0.178***	-0.155***	-0.207***	-0.0428	-0.0231	-0.0613
	(0.0329)	(0.0467)	(0.0460)	(0.0281)	(0.0349)	(0.0459)
Treat x Prod. period	-0.138***	-0.102**	-0.177***	-0.199***	-0.103**	-0.268***
	(0.0289)	(0.0427)	(0.0391)	(0.0380)	(0.0502)	(0.0541)
Observations	7,645	3,686	3,958	4,112	1,849	2,263
R-Squared	0.410	0.364	0.455	0.065	0.053	0.102
Controls	YES	YES	YES	YES	YES	YES
Parallel trend	No	Yes	Yes	Yes	No	Yes
Pre-treatment mean of the treated	0.286	0.273	0.299	0.980	0.981	0.980

Note: youth includes individuals below 25 years of age. Adult includes individuals above 25 years of age. Controls include: district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.

Table A6: Robustness check, sensitivity check of the control group, economic indicators (full sample)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Excluding PA from:		C. Delgado	Gaza	Inhambame	Manica	Niassa	Sofala	Zambezia
Panel A: dependent variable: log of per capita consumption								
Treat x Inv. period	0.444***	0.432***	0.399***	0.629***	0.389***	0.445***	0.413***	0.397***
	(0.0492)	(0.0492)	(0.0497)	(0.0500)	(0.0501)	(0.0496)	(0.0491)	(0.0502)
Treat x Prod. period	0.395***	0.371***	0.356***	0.567***	0.360***	0.372***	0.432***	0.343***
	(0.0456)	(0.0457)	(0.0459)	(0.0458)	(0.0463)	(0.0459)	(0.0464)	(0.0463)
Panel B: dependent variable: poor								
Treat x Inv. period	-0.208***	-0.202***	-0.196***	-0.292***	-0.165***	-0.214***	-0.198***	-0.170***
	(0.0375)	(0.0375)	(0.0379)	(0.0383)	(0.0378)	(0.0377)	(0.0374)	(0.0379)
Treat x Prod. period	-0.116***	-0.106***	-0.101***	-0.213***	-0.0832***	-0.104***	-0.146***	-0.0779***
	(0.0292)	(0.0293)	(0.0294)	(0.0300)	(0.0296)	(0.0294)	(0.0297)	(0.0298)
Panel C: dependent variable: poverty gap								
Treat x Inv. period	-21.23***	-20.76***	-19.57***	-27.36***	-19.38***	-21.32***	-19.90***	-19.50***
	(1.718)	(1.716)	(1.748)	(1.766)	(1.751)	(1.730)	(1.712)	(1.751)
Treat x Prod. period	-13.21***	-12.29***	-11.81***	-18.23***	-12.67***	-12.34***	-14.39***	-11.28***
	(1.489)	(1.489)	(1.502)	(1.510)	(1.512)	(1.495)	(1.516)	(1.510)
Panel D: dependent variable: poverty gap squared								
Treat x Inv. period	-15.70***	-15.41***	-14.43***	-19.70***	-14.63***	-15.60***	-14.91***	-14.81***
	(1.163)	(1.163)	(1.178)	(1.195)	(1.184)	(1.170)	(1.167)	(1.184)
Treat x Prod. period	-10.50***	-9.883***	-9.546***	-13.38***	-10.37***	-9.875***	-11.31***	-9.368***
	(1.070)	(1.069)	(1.077)	(1.083)	(1.084)	(1.074)	(1.088)	(1.079)
Observations	12,608	12,207	11,187	9,562	11,505	11,949	10,433	11,052

Note: controls include district fixed effects, year fixed effects, survey quarter fixed effects, age, and education. Standard errors are robust.

Source: authors’ estimation based on IAF/IOF data.

Table A7: Robustness check, different levels of fixed effects, economic indicators

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Full sample			Female sample			Male sample	
	Prov. FE	District FE	PA FE	Prov. FE	District FE	PA FE	Prov. FE	District FE	PA FE
Panel A: dependent variable: log of per capita consumption									
Treat x Inv. period	0.440***	0.444***	0.446***	0.431***	0.439***	0.441***	0.450***	0.451***	0.453***
	(0.0481)	(0.0492)	(0.0494)	(0.0686)	(0.0702)	(0.0704)	(0.0674)	(0.0692)	(0.0697)
Treat x Prod. period	0.392***	0.395***	0.399***	0.402***	0.408***	0.408***	0.382***	0.381***	0.389***
	(0.0467)	(0.0456)	(0.0458)	(0.0689)	(0.0676)	(0.0678)	(0.0634)	(0.0616)	(0.0620)
Panel B: dependent variable: poor									
Treat x Inv. period	-0.199***	-0.208***	-0.216***	-0.159***	-0.167***	-0.174***	-0.240***	-0.249***	-0.259***
	(0.0368)	(0.0375)	(0.0377)	(0.0518)	(0.0528)	(0.0531)	(0.0521)	(0.0531)	(0.0537)
Treat x Prod. period	-0.106***	-0.116***	-0.122***	-0.0914**	-0.101**	-0.103**	-0.120***	-0.130***	-0.138***
	(0.0293)	(0.0292)	(0.0293)	(0.0423)	(0.0422)	(0.0423)	(0.0407)	(0.0406)	(0.0408)
Panel C: dependent variable: poverty gap									
Treat x Inv. period	-20.94***	-21.23***	-21.37***	-21.65***	-22.08***	-22.22***	-20.18***	-20.30***	-20.49***
	(1.702)	(1.718)	(1.723)	(2.397)	(2.411)	(2.414)	(2.425)	(2.456)	(2.470)
Treat x Prod. period	-12.91***	-13.21***	-13.47***	-13.82***	-14.31***	-14.35***	-11.91***	-12.04***	-12.46***
	(1.488)	(1.489)	(1.496)	(2.126)	(2.134)	(2.144)	(2.090)	(2.082)	(2.097)
Panel D: dependent variable: poverty gap squared									
Treat x Inv. period	-15.69***	-15.70***	-15.69***	-16.87***	-16.98***	-16.98***	-14.46***	-14.36***	-14.35***
	(1.163)	(1.163)	(1.162)	(1.652)	(1.651)	(1.648)	(1.639)	(1.643)	(1.644)
Treat x Prod. period	-10.50***	-10.50***	-10.62***	-11.62***	-11.74***	-11.71***	-9.324***	-9.213***	-9.449***
	(1.073)	(1.070)	(1.074)	(1.528)	(1.528)	(1.535)	(1.504)	(1.494)	(1.502)
Observations	12,608	12,608	12,608	5,947	5,947	5,947	6,660	6,660	6,660

Note: controls include fixed effects as indicated in the table, year fixed effects, survey quarter fixed effects, age, and education.. Standard errors are robust.

Source: authors' estimation based on IAF/IOF data.