

# A Natural Resource Curse: The Unintended Effects of Gold Mining on Malaria

Jeffrey Pagel <sup>\*†</sup>

*July 2023*

## Abstract

This paper studies whether extractive-resource-activities provoke an ecological response on the emergence and proliferation of malaria by altering the reproductive environment of mosquitoes. In January 2004, the government of the Philippines launched the Minerals Action Plan (MAP), which significantly improved the investment climate in the country's mining sector. I exploit the timing of the reform and the spatial distribution of mineral endowments through a difference-in-differences (DID) approach that compares provinces with and without gold deposits before and after the reform. After the MAP reform, provinces with deposits of gold had 32 percent more malaria cases per 100,000 relative to provinces without gold deposits. I perform several falsification tests as well as investigate other potential mechanisms which further suggest that the main mechanism is through gold mining's creation of slow-moving bodies of stagnant water, which provide an ideal breeding site for *Anopheles* mosquitoes, malaria's main transmission vector, to propagate and reproduce.

**Keywords:** Natural Resource Curse, Malaria, Extractive Resources, Health and Economic Development

**JEL:** Q32, Q57, I18

---

<sup>\*</sup>Department of Geography and Environment, London School of Economics and Grantham Research Institute; Email: [j.pagel@lse.ac.uk](mailto:j.pagel@lse.ac.uk)

<sup>†</sup>I am grateful to my advisors Alfonso Herranz-Loncán and Miquel-Àngel Garcia-López for their generous advice and encouragement. I would also like to thank François Cohen, Doug Gollin, Hendrik Wolff, Gordon McCord, Rodrigo Martínez-Mazza, and Owen Ozier for valuable comments and discussions as well as conference and seminar participants at CSAE Conference (University of Oxford), NEUDC (Yale University), Midwest International Economic Development Conference (Northwestern University), PhD Workshop in Empirical Economics (Potsdam University), Shifting Landscapes (LSE), 100 Years of Economic Development (Cornell University), Grantham Policy Design and Evaluation Workshop (LSE), San Diego State University, Marquette University and Universitat Autònoma de Barcelona. Financial support is gratefully acknowledged from the Grantham Foundation for the Protection of the Environment and the Government of Catalonia - AGAUR and European Social Fund (FI-DGR).

# 1 Gold mining and its unintended effects on malaria

The relationship between people and the environment is important for human health. One aspect we have little understanding of is whether and how national policy might have negative effects on human health through altering the local ecology. As the environment undergoes continuous modifications, primarily due to activities such as land transformation and clearance, it is highly likely that we will witness a persistent increase in the prevalence of diseases.<sup>1</sup> Development policy that facilitates land transformation and clearance activities may create unintended negative externalities and understanding these costs is important in devising an appropriate policy response.

This paper analyzes a change in development policy and whether there is an ecological response from extractive-resource-activities that influence the emergence and proliferation of malaria by altering the reproductive environment of mosquitoes. More specifically, in this study I analyze the effects that gold mining activities have on the incidence of malaria through a nation-wide reform that improved the investment climate in the Philippines' mining sector. In January 2004, the government of the Philippines launched the Minerals Action Plan (MAP) with the goal of revitalizing the mining sector through an executive order ([Executive Order No. 270-A, 2004](#)). The main objective of the reform was to increase both foreign and domestic investment in the mining sector and alleviate poverty in the areas where mining activities take place. Ultimately the mining reform led towards a more extractive resource policy by streamlining the application process for mining permits, increasing the number of issued permits, and made it more difficult to hold up operations through legal challenges. As a result of the reform, the mining permit process reduced the average lag between application and grant of a permit from 3-5 years to 6 months in 2005 ([Fong-Sam, 2005](#)). Additionally, the reform is estimated to have generated around \$5 billion worth of commitments for new investments by February 2005 ([Cruz et al., 2005](#); [Fong-Sam, 2005](#)).

Using the MAP reform, I exploit two sources of variation in the timing of the reform as well as spatial variation in the distribution of mineral endowments through a difference-in-differences (DID) approach that compares provinces with and without gold deposits before and after the reform. This study estimates how a shift in national policy towards a more extractive resource position in the mining sector led to an unintended ecological response regarding an increase in the incidence of malaria. Gold mining sites are typically located within or close to water surfaces, where mines are dug and filled with water. If the gold mines are not properly filled back in, slow-moving bodies of stagnant water provide the ideal breeding environment for the *Anopheles* mosquito that carries the malaria disease.

I find evidence that is consistent with an ecological response, where the MAP reform had a statistically significant effect on the incidence of malaria. After the MAP reform, provinces with deposits of gold had 32 percent more malaria cases per 100,000 relative to provinces without

---

<sup>1</sup>Roughly one quarter of the global burden of disease can be attributed to environmental changes ([Prüss-Üstün et al., 2008](#)).

gold deposits. Additionally, I use an event study approach to shed light on the yearly dynamics of the MAP reform as well as show that the long-run effects on malaria are persistent 10 years beyond the implementation of the policy. In order to reinforce the empirical strategy, I perform several falsification tests. The first test exploits differences in disease ecology, where I find no evidence that gold mining after the MAP reform had an effect on other diseases. Second, I exploit differences across location and extraction factors from other types of minerals, where I find no evidence of an effect on malaria. Third, I perform a randomization inference exercise where provinces are randomly selected to be treated by gold deposits to show that the causal impacts are not likely to be randomly generated. Lastly, I examine other possible mechanisms such as migration or deforestation and find that neither can explain the increase in malaria, further suggesting that the causal mechanism is running through gold mining's creation of slow moving bodies of stagnant water.

Several contributions are made to the literature. To the best of my knowledge, this is the first study to provide causal evidence on how a national policy reform can have severe unintended consequences on human health by changing the local ecology. Furthermore, this study provides the first nation-wide estimates for the impact of gold mining on the incidence of malaria. This substantially differentiates from the previous literature that has focused on a subset of geographic areas within a country and localized effects of malaria (Rozo, 2020; De Santi et al., 2016; Valle and Lima, 2014) or other health outcomes (von der Goltz and Barnwal, 2019). Second, obtaining causal estimates of the health consequences of environmental quality is challenging (Greenstone and Jack, 2015). Moreover, much of the previous literature has focused on a correlation between gold mining and malaria (De Santi et al., 2016; Barbieri et al., 2005; Castellanos et al., 2016). This study moves beyond a correlation to provide causal estimates by exploiting the timing of the reform as well as the spatial distribution of geological endowments. Third, this national policy encouraged the expansion of legal mining operations and made it much easier to obtain mining permits. This differentiates from the context of Rozo (2020) that focused on illegal gold mining, with a bulk of the argument for the increased incidence of malaria placed on the fact that illegal gold miners do not comply with the rules and have limited knowledge of measures needed to protect themselves against malaria or prevent the reproduction of mosquitoes. Evidence from this study indicates that this is not necessarily the case as a legal expansion of the resource extraction sector through the MAP reform led to an increase in the incidence of malaria. Last, many studies estimating the health consequences of environmental quality face limitations when it comes to long-run impacts (Greenstone and Jack, 2015). By exploiting over ten years of panel data, I am able to document the long-run impact and show that the reform has persistent effects on malaria 10 years beyond the implementation of the policy. This contribution highlights how negative externalities derived from policies may persist decades beyond their implementation.

While much of the existing evidence on malaria incidence and gold exploitation has been concentrated on qualitative studies or on documenting correlations, the detection of large-scale effects or causal estimates between the two is rare. In general, an association has been

described in the literature between the proximity to gold mining operations and the risk of malaria ([Barbieri et al., 2005](#); [Crompton et al., 2002](#)). [Barbieri et al. \(2005\)](#) find an association between malaria prevalence and small-scale gold mining in Northern Mato Grosso of Brazil. In the Brazilian Amazon, [Valle and Lima \(2014\)](#) find that an important predictor of malaria incidence is the proximity to gold mining operations, because high migration rates are often associated with artisanal gold mining. [Rozo \(2020\)](#) investigates the effect of illegal gold mining on malaria incidence in western Colombia by exploiting pre-existing geochemical gold anomalies through an instrumental variable approach and shows that there are positive and large effects of illegal gold mining on malaria incidence. Estimates suggest that when areas that contain an illegal gold mine increase by 1 hectare, the annual parasite index for malaria increases by 1.04 cases per 100,000 inhabitants.

Additionally, this study contributes to the literature on the effects mining has on health and well-being, with a particular emphasis on the direct effects. On one side, mining has been shown to have indirect effects on health and well-being. [Benshaul-Tolonen \(2019\)](#) examines the expansion of large-scale gold mining throughout sub-Saharan Africa and finds that local infant mortality rates decrease by more than 50 percent as a result, where the reduction in child mortality is likely due to women’s improved access to market opportunities and health care facilities. By assessing the health and wealth impacts of mineral mining from about 800 mines in 44 developing countries, [von der Goltz and Barnwal \(2019\)](#) find that communities exposed to mining enjoy important economic benefits in the medium and long-term, but there are serious health impacts such as an increase in anemia by three to ten percentage points for adult women and an impaired ability to recover hemoglobin levels after blood loss due to pregnancy and delivery. Additionally, [Parker et al. \(2016\)](#) investigate the effects of the Dodd-Frank Act that discouraged companies from sourcing minerals from the Democratic Republic of Congo. The authors find that the policy increased the probability of infant deaths in villages near the policy-targeted mines by at least 143 percent, and present suggestive evidence that the underlying mechanism is through a reduction in mothers’ consumption of infant health care goods and services. On the other side, mining has been shown to have direct effects on health and well-being. High concentrations of particulate matter that are common in close proximity to opencast mines have been shown to increase respiratory disorders ([Hedlund et al., 2006](#); [Ross and Murray, 2004](#)).

Last, this study broadly contributes to the strand of literature on negative externalities of mining and extractive resources. [Crost and Felter \(2020\)](#) analyze the MAP to find that the reform led to a large increase in violent conflict, which was most likely due to an increase in competition over control for resource-rich areas. Politically, mining has been shown to increase rent-seeking behavior, conflict and political corruption ([Caselli and Michaels, 2013](#); [Berman et al., 2017](#); [Adhvaryu et al., 2020](#)) as well as fuel repressive or destructive activities ([Acemoglu and Robinson, 2001](#); [Caselli and Tesei, 2016](#); [Dube and Naidu, 2015](#); [Mitra and Ray, 2014](#); [Nunn and Qian, 2014](#)). Resource booms additionally increase the value of being in power and provide politicians with more resources to exert their influence on the outcome of elections as

well as increase resource misallocation to the rest of the economy (Robinson et al., 2006). Large-scale gold mining has been shown to decrease total factor productivity by almost 40 percent in Ghana, with the likely mechanism being the release of environmental pollutants (Aragón and Rud, 2016). In terms of environmental effects, gold mining has been shown to have long-lasting effects which include air, soil and water pollution from arsenic, cyanide and mercury (Eisler, 2004; Veiga et al., 2006; Gerson et al., 2022). Furthermore, the pollutants released from gold mining activities can travel through rivers and tributaries, which negatively affect the water quality for humans, fish and other wildlife (Uryu et al., 2001). Last, mining has been shown to increase deforestation (Austin et al., 2019; Baliatti et al., 2018; Recht et al., 2017).

The paper is structured as follows. Section 2 describes the gold mining industry in the Philippines, provides an overview of malaria such as what malaria is, the environments in which it persists, malaria’s relationship to mining and lastly describes the data used in the analysis. Section 3 outlines the empirical strategies, identifying assumptions, and the model to be estimated. Section 4 presents the main results, performs several robustness tests of the main specification, and estimates an event study specification. Section 5 performs several falsification tests to reinforce the empirical strategy. Section 6 investigates other potential mechanisms through which malaria may be exacerbated such as migration or deforestation. Section 7 outlines several policy responses and provides concluding remarks.

## 2 Background and data

### 2.1 Gold mining in the Philippines

The Philippines is the fifth most mineral-rich country in the world for gold, nickel, copper, and chromite. In 2010, the value of its known mineral reserves was estimated at over 1.3 trillion U.S. dollars (Pavlova and Hincks, 2013). The Philippines’ largest mineral exports are gold, copper and nickel, which make up over 97 percent of the country’s total mineral production. Gold alone accounts for approximately 68 percent of the total value of mineral production in the country.

After decades of low production and exports, the MAP sought to boost the economy by streamlining the application process for mining permits, increase the number of issued permits, and make it more difficult to hold up operations through legal challenges. The policy governs all mining operations in the country and covers the facilitation of investments, optimizes the benefits from minerals, promotes small-scale mining, and implements the use of efficient technology (Executive Order No. 270-A, 2004). This is done by harmonizing provisions of laws affecting mining, and facilitating greater investment in the mining industry by local and foreign companies.

While the Department of Environment and Natural Resources (DENR) and the Mines and Geosciences Bureau (MGB) are responsible in awarding mining permits, provincial governors or city mayors can issue permits for small-scale metal mining, sand and gravel extraction

and, quarrying where the maximum contract area is limited to 20 hectares. In practice, local executives (particularly the provincial governor) retain a high degree of control over the issuance of these permits (Verbrugge, 2014). According to DENR officials and other sources, governors and mayors exert significant influence on the Local Board regarding the number and distribution of small-scale mining permits (Sunley et al., 2012). Additionally, since there is a difference in the fiscal regimes for small-scale and larger mines, local governments are incentivized to provide many small-scale mining permits and to oppose large-scale mining (Sunley et al., 2012).

Small-scale mining plays a significant role in gold extraction in the Philippines, and various gold mining techniques are employed to extract this precious metal from the country's rich mineral reserves. One of the traditional methods utilized is placer mining, which involves the extraction of gold from rivers, streams, puddles or pits through panning or sluicing to separate gold particles from the surrounding sediment. Other methods employed are the construction of shallow underground mining tunnels to access gold-bearing veins or compressor mining which are simple shafts about a square meter in size and filled with water. Each of these methods involve varying degrees of capitalization from outside financiers, which can include basic tools, pneumatic drills, excavators, explosives, 2-MW diesel generators, water pumps, and mine carts, as well as food and shelter for the labor force.

Since 2005, the mining industry in the Philippines has experienced a resurgence, and is expected to attract more investments and generate more jobs and revenues for both the National Government and Lower Government Units (LGUs) in the coming years (Soriano and Makayan, 2012). One way to see this growth is through gold sales to the Central Bank. Small-scale gold miners are required to sell all the gold they produce to the *Bangko Sentral ng Pilipinas* (Central Bank of the Philippines), or its duly authorized representatives at prices competitive with those prevailing in the world market regardless of volume or weight (Republic Act 7076, 1991). Figure 3 presents data on the total reserves of gold held by the Central Bank of the Philippines in current US dollars. Although these figures likely represent a significant underestimation, especially when accounting for the extensive history of illicit cross-border trade, they nonetheless still provide an important indication of trends in small-scale gold mining (Verbrugge, 2014). Additionally, Figure 4 presents data on mineral depletion in current US dollars and mineral rents as a percentage of GDP. Each of these figures provide evidence that the MAP reform changed mining activity in the Philippines and illustrate the growth that took place in the mining sector after 2004.

## 2.2 Malaria ecology

In 2018, the World Health Organization (2019) estimated 228 million cases of malaria occurred worldwide, of which approximately 405,000 resulted in death. Despite billions of dollars in investments, approximately one-third of the world (2 billion people) still live in areas infected by malaria, and more people die from it than 40 years ago (Pattanayak and Pfaff,



2009).<sup>2</sup>

Malaria is an infectious disease that is exclusively transmitted through female *Anopheles* mosquitoes. Transmission occurs after a mosquito becomes infected with malaria by biting an infected person and then the infected mosquito bites a non-infected person.<sup>3</sup> *Anopheles* first take up a sexually differentiated form of the Plasmodium parasite which undergo reproduction in the mosquito, then the resulting sporozoite forms travel to the salivary glands and are injected into a potential host during the mosquitoes next blood meal (Sinden and Gilles, 2002; Service and Townson, 2002).<sup>4</sup> On average, female *Anopheles* have a lifespan of approximately 2-3 weeks, depending on environmental factors, and are not usually found more than 2-3km from their breeding sites (Service and Townson, 2002). Figure 1 presents data on the number of reported cases and incidence of malaria in the Philippines. Despite a recent decrease, the number of yearly cases is still high. Additionally, the World Health Organization (2019) estimates that the population at risk of malaria in the Philippines has been increasing from 54.4 million in 2010 to 61.9 million in 2018.

Malaria is typically found in tropical and subtropical countries, where higher temperatures allow the *Anopheles* mosquito to thrive. Environmental changes either through natural phenomenon or human intervention can alter the ecological balance within which vectors and their parasites breed, develop and transmit disease. Ecosystem changes, particularly land transformation, profoundly impact breeding sites, survival probability, density, biting rates, and incubation periods (Service and Townson, 2002; Snow and Gilles, 2002; Pattanayak and Yasuoka, 2012). Additionally, geo-climatic factors such as altitude, climate, temperature and weekly rainfall intensity determine the presence of *Anopheles* breeding sites, vector densities, adult mosquito survival rate, longevity and vector capacity (Imbahale et al., 2011; Texier et al., 2013). Among the various environmental or land-use factors that determine the transmission of malaria, stagnant or slow-moving bodies of water are the most important because they provide the basic requirement for the presence of breeding sites for the occurrence of the *Anopheles* vectors.

The basic pathway in which gold mining can accelerate the reproductive environment of the *Anopheles* mosquito is through the process of leaving behind slow-moving bodies of water, which happen to be the common location of many gold mines. Miners search for gold deposits, where they either dig shallow underground tunnels or they dig small holes or shafts along the

---

<sup>2</sup>In 2018, governments of malaria endemic countries and international partners invested approximately \$2.7 billion in malaria control and elimination efforts (World Health Organization, 2019).

<sup>3</sup>Malaria causes flulike symptoms that may include fever, chills, muscle aches, headache, nausea and in the most severe cases in which the parasite travels to vital organs such as the brain, can lead to seizures, coma and in 20-50 percent of cases, death (Gilles et al., 1996). Malaria also causes morbidity through fever, weakness, malnutrition, anemia, spleen diseases, and vulnerability to other diseases (Pattanayak and Pfaff, 2009).

<sup>4</sup>While there is great diversity in the *Anopheles* mosquito species that carry the malaria disease and cases can be classified into each of the five species of parasites, the data to be employed in this analysis only report the general number of malaria cases. However, The Centers for Disease Control and Prevention estimate that 70-80 percent of mosquitoes in the Philippines are *P. Falciparum* and 20-30 percent are *P. Vivax*, and *P. Knowlesi* are rare (Arguin and Tan, 2017).

rivers and fill them with water. The idea is to separate the heavier gold pieces from the dirt, and when the miners are done they leave pools of water behind. In particular, if these stagnant pools of water are left open, they can provide an ideal breeding site for the *Anopheles* mosquito to reproduce.<sup>5</sup>

## 2.3 Data

The main analysis is based on a province-by-year dataset constructed from various types of data: health reports, digitized geological maps, census records, and remotely sensed data. Table A.1 in Appendix A.1 provides summary statistics for each of the variables used in the analysis.

**Malaria Data:** The Department of Health (DOH) and the National Statistics Office (NSO) provide a yearly summary of natality, morbidity, and mortality across the Philippines. The reporting of diseases is mandatory by virtue of the Law on Reporting of Communicable Diseases ([Republic Act 3573, 1929](#)). Data within the health reports comes from an annual consolidation of the weekly notifiable disease reports from village health stations and rural health units. The consolidation is done yearly at the provincial/city and regional levels.<sup>6</sup> The health reports provide the yearly number of malaria cases per 100,000 individuals at the provincial level. According to [Sachs \(2003\)](#), even deaths due to malaria are often unreported due to other causes but are attributed to malaria since the individual may simultaneously be infected by malaria or alternatively some deaths may be attributed to other causes and have malaria as a co-factor, but not the principal cause. Provinces averaged 1.04 malaria cases per 100,000 individuals over the sample period.

**Mining Data:** I digitize geological maps from the MGB which is a part of the DENR. These maps provide information on the mineral deposit potential of nickel, manganese, iron, gold, chromium, and copper deposits. In Figure 2, the left panel presents data on gold deposits throughout the Philippines, showing the spatial variation of provinces with and without gold deposits, while the right panel combines the two main data sources to illustrate the geographic dispersion of mineral deposits along with the incidence of malaria. Provinces with gold deposits make up 45 percent of the sample.

**Other Variables:** Additional control variables are included and broken down into geographic and socioeconomic controls. Geographic variables such as air temperature and precipitation come from [Harris et al. \(2020\)](#). Socioeconomic variables come from the census of the Philippines in 2000 and 2010. Last, small area poverty estimates are obtained from the Philip-

---

<sup>5</sup>The majority of *Anopheles* larval habitats are found in freshwater sources of water such as small pools of water, puddles, seepages in forests, footprints, mining pits and irrigation ditches that provide areas for mosquitoes to deposit eggs ([World Health Organization, 1982](#); [Service and Townson, 2002](#)). Although most aquatic larval habitats are within freshwater, some *Anopheline* species breed in saline or brackish water ([Kiszewski et al., 2004](#); [Service and Townson, 2002](#)).

<sup>6</sup>Data on malaria cases within the health reports are provided at the province level and cannot be disaggregated to a smaller spatial unit.



pine Statistics Authority (PSA) which produces estimates of poverty incidence every three years from 2000 – 2018.

### 3 Identification and empirical strategy

In order to measure how the MAP reform affected the incidence of malaria, a DID empirical strategy is employed that exploits the subsequent reduction in the average lag between application and grant of a mining permit from 3-5 years to 6 months. Using this reform, I exploit the timing as well as the spatial distribution of mineral reserves that compares provinces with and without gold deposits before and after the reform.

There are several key assumptions that must be met to assure the validity of the DID empirical strategy. The first is the parallel trends assumption, which is intended to show that there are no time-varying differences between the treatment and control areas in the absence of treatment. If the trends of the treatment and control groups moved in tandem before the MAP reform, then they likely would have continued moving in tandem in the absence of the reform. In order to check for parallel trends, at least two serial observations on the treatment and comparison groups are needed before the start of the reform (Gertler et al., 2016). Figure 5 shows that before the 2004 MAP reform, the number of malaria cases decreased at a similar rate in both groups but after the reform the number of cases in provinces with gold deposits first increased and then converged with non-gold provinces. Additionally I use census data prior to the reform to see whether there are differences between gold and non-gold mining provinces. Table 1 shows that gold mining and non-gold mining provinces are statistically indistinguishable across various covariates used in the analysis, except population. Last, results from an event study specification (see below, Section 4.2) shows that provinces with or without gold deposits prior to the MAP reform are not statistically distinguishable from one another in terms of malaria cases. Provinces with deposits of gold only started experiencing higher levels of malaria and in a timely fashion around the introduction of the MAP reform. Each of these pieces of evidence provide a compelling argument in support of the parallel trends assumption.

The other set of assumptions have to deal with the exogeneity of gold deposits. First is the location of gold deposits. A necessary assumption for the presence of a gold mine is a gold deposit, which is a geological anomaly and random (Eggert, 2002). Additionally, Bazillier and Girard (2020) argue that gold deposits are exogenously determined by the geological environment. A second assumption is whether the reform led to the discovery of entirely new deposits in provinces that previously had no known deposits. As Crost and Felter (2020) point out, the approximate location of mineral deposits in the Philippines has been known for decades.

In order to estimate a causal effect of the MAP reform on the incidence of malaria, I estimate the following equation that takes advantage of a DID stemming from the timing of the reform’s implementation and the location of gold deposits from 2002 and 2015. The equation to be estimated is:

$$Malaria_{p,t} = \beta_0 + \beta_1 MiningReform_t \cdot Gold_p + X'_{p,t} \cdot \delta + \rho_p + \tau_t + \epsilon_{p,t} \quad (1)$$

where  $Malaria_{p,t}$  is estimated for the inverse hyperbolic sine of malaria cases for province  $p$ , in year  $t$ .<sup>7</sup> The main independent variable is the interaction between  $MiningReform_t$ , which is a dummy variable indicating before or after the MAP reform in 2004 and the variable  $Gold_p$  which is a dummy variable indicating whether the province has gold deposits. Furthermore,  $X'$  is a vector of geographical and province level socioeconomic covariates which include: the poverty incidence level, log of population, log of deforestation, mean air temperature, mean precipitation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water.<sup>8</sup> Some control variables are potentially endogenous, and are also considered to be possible mechanisms; I therefore test several specifications that omit the full set of controls, include different sets of control variables or include a full set of control variables. The results remain stable across each of these specifications. The intercept term is represented as  $\beta_0$ , while province and time fixed effects are denoted as  $\rho_p$  and  $\tau_t$ , respectively, which control for the unobserved provincial-time-invariant effect. Throughout the analysis, standard errors are clustered at the province level, to account for the arbitrary correlation within the province in terms of spatial autocorrelation and serial correlation over time. I then perform a battery of robustness checks which include: testing the stability of the coefficients by dropping each province with gold deposits in turn, controlling for the number of rural health clinics, controlling for intermediate values of temperature and precipitation, controlling for quadratic time trends, testing an alternative log transformation of the dependent variable and lastly looking at the intensive margin with the number of gold mine deposits.

---

<sup>7</sup>Since some provinces did not experience any cases of malaria, it is more appropriate to use the inverse hyperbolic sine (IHS) transformation of malaria cases in order to accommodate provinces that had zero cases or an undefined log transformation. The IHS transformation approximates the natural logarithm and allows for retaining zero-valued observations (Bellemare and Wichman, 2020) and contrary to the logarithm is well defined around zero (Card and DellaVigna, 2020). The IHS function approximates the log function except for values close to 0, for which it approximates  $\ln(x) + \ln(2)$ . Using the absolute measure of malaria cases, the IHS function is constructed as:  $IHSMalaria_{p,t} = \ln(Malaria_{p,t} + \sqrt{Malaria_{p,t}^2 + 1})$ .

<sup>8</sup>Ethnic and religious fractionalization are computed using a standard Herfindahl index. Let provinces  $p$  be  $p = 1, \dots, P$  and  $N$  represent the number of ethnicities or religions. Ethnic fractionalization (EF) and religious fractionalization (RF) in province  $p$  is given by:  $EF_p = 1 - \sum_{i=1}^N s_{p,i}^2$  or  $RF_p = 1 - \sum_{i=1}^N s_{p,i}^2$  where  $s_{p,i}$  is the share of ethnicity or religion  $i$  in province  $p$ , respectively.

## 4 Results

Table 2 presents the main results. The main finding from the preferred specification in column 4 is that provinces with gold deposits after the MAP reform experience 32 percent more malaria cases per 100,000 relative to provinces without gold deposits. The baseline results in column 1 are robust to the inclusion of geographic controls in column 2, socioeconomic controls in column 3 as well as to the inclusion of both geographic and socioeconomic controls in column 4.<sup>9</sup> The robustness of the results across various specifications, even with the inclusion of socioeconomic controls indicate that the underlying mechanisms is through an ecological response rather than a socioeconomic response. Additionally, some may argue that the MAP reform or the increase in the mining sector might have led to an increase in the measurement of malaria. In section 5.1, I will show through a series of falsification tests that the reform had no effect on other diseases and therefore it is unlikely that there was an increase in the measurement of malaria or of other diseases more broadly.

### 4.1 Robustness tests

In order to document the stability of the estimates more generally, I perform several robustness checks of the main estimation. First I re-estimate equation (1) and drop each province with gold deposits in turn. Figure A.1 then plots each of the estimated coefficients to illustrate their stability and demonstrate that the coefficients continue to be significant at conventional levels. This exercise additionally indicates that no single province is driving the main results in Table 2. Second Bauhoff and Busch (2020) argue that access to local health services affects malaria. In Table A.3 I control for the number of rural health facilities within a province. Regardless of controlling for the number of rural health facilities, the results remain similar to Table 2. Third previous literature argues that malaria risk is highest at intermediate values of temperature and precipitation (Beck-Johnson et al., 2013; Mordecai et al., 2013; Parham and Michael, 2010). Table A.4 tests the sensitivity of the results by additionally controlling for squared terms of temperature and precipitation and the results remain unchanged. Fourth I additionally control for quadratic time trends in the main specification and the results in Table A.5 remain qualitatively similar. Fifth, in addition to defining malaria in either the level or IHS transformation, I also test the sensitivity of the main results by defining malaria cases as  $\log(1 + \text{MalariaCases})$ . Thus, in Table A.6 I show that the alternative transformation of the dependent variable does not qualitatively change the results in Table 2. Last, in Table A.7, I look at the intensive margin with the number of gold mine deposits within a province, where the estimated coefficients point in the same direction, but are not statistically significant at

---

<sup>9</sup>In Table A.2 I estimate equation (1) and show that the results are robust to using non-transformed malaria cases as the dependent variable. After the MAP reform, provinces with gold deposits experienced an increase of 2.3 more malaria cases per 100,000 relative to provinces without gold deposits.

conventional thresholds of significance.<sup>10</sup>

## 4.2 Event study specification

Estimates in Table 2 represent a weighted average of the MAP reform and gold deposit effects by year, and thus do not provide information on the magnitude of the effects over time. To further examine and uncover the dynamic effects of the MAP reform and gold deposits, I estimate the following event study specification:

$$Malaria_{p,t} = \rho_p + \tau_t + X'_{p,t} \cdot \delta + \sum_{\phi=-1}^m \beta_{-\phi} D_{i,t-\phi} + \sum_{\phi=0}^q \beta_{+\phi} D_{i,t+\phi} + \epsilon_{p,t} \quad (2)$$

where  $D_{i,t-\phi}$  estimates the leads and  $D_{i,t+\phi}$  the lags of the treatment dummy in order to decompose the treatment effect for each year preceding and following the MAP reform. I take the year of the MAP reform as the omitted baseline year of comparison and make all estimates relative to 2004.

This specification is advantageous for two main reasons. The first advantage is to test whether there was any anticipatory behavior prior to the treatment. This is an intuitive way to test for Granger causality (Tewari, 2014) and check whether the pre-policy coefficients are insignificant and display no trend. Instead of controlling for differential pre-MAP trends across provinces, the specification directly tests for the existence of such differentials without imposing a linear structure on the time pattern related to the reform. Insignificant coefficients prior to the reform provide some reassurances to the identifying assumptions of the DID. The second advantage is the ability to trace out the full dynamic trajectory as well as the persistence of the effects.

Results from the estimated equation (2) are plotted in Figure 6. First, there does not appear to be any anticipatory effect as the point estimates prior to the reform are insignificant. This result offers evidence that provinces with gold deposits and provinces without gold deposits had similar evolutions in cases of malaria prior to the MAP. Second, the effect on malaria is immediately experienced in 2005. Immediately following the MAP reform, provinces with gold deposits experience 46 percent more malaria cases relative to provinces without gold deposits. The estimated yearly effects remain fairly stable between 30 and 60 percent. Last, the figure illustrates how persistent the effects are in that more than 10 years after the reform the effects are still significant.

---

<sup>10</sup>Table A.8 presents estimates at the intensive margin using an absolute measure of malaria cases and find a positive and statistically significant impact.

## 5 Falsification tests

Now that it has been established that provinces with gold deposits after the MAP reform experienced an increase in the number of malaria cases relative to provinces without gold deposits, the study now moves to reinforce the empirical strategy. This section performs several falsification tests by investigating 1) whether gold mining has an effect on other diseases through differences in disease ecology; 2) whether other mineral deposits have an effect on malaria; and 3) a randomization inference exercise where provinces are randomly selected to be treated with gold deposits.

### 5.1 Other diseases

One threat to the validity of the empirical strategy would be if there are unobserved variables that are correlated with both human health outcomes and gold mining deposits that might have an impact on other diseases other than malaria. An important aspect to determine is whether the established relationship between gold mining and the incidence of malaria is specific to the disease ecology of malaria and not generically to other health outcomes. To perform this analysis, this section maintains the same empirical structure as equation (1), but will test the effects of the MAP reform and gold deposits on other diseases such as dengue, HIV, lower respiratory infections, pneumonia and gastric or duodenal peptic ulcers. This follows similar falsification tests performed by [Garg \(2019\)](#) and [Rozo \(2020\)](#) that exploit different epidemiological mechanisms of transmission across diseases. [Garg \(2019\)](#) uses the health measures of measles, diarrhea, respiratory infections and dengue, while [Rozo \(2020\)](#) uses skin rashes, abortion rates, fetal malformation, respiratory, and digestive diseases.<sup>11</sup>

Table 3 reports the results of the falsification tests, where I find no evidence of an effect that provinces with gold deposits after the reform had an effect on the number of dengue, HIV, lower respiratory infections, pneumonia or gastric or duodenal peptic ulcer cases. These results indicate that the main channel is through the ecological response of altering the reproductive environment that is specific to malaria.

### 5.2 Other minerals

The next falsification test investigates whether the increased incidence of malaria is specific to gold mining, or mining in general. It could be argued that mining in general may have the same negative externalities and that there is nothing particular about gold mining that leads

---

<sup>11</sup>The disease ecology of malaria differs significantly from dengue even though they are both spread via disease carrying vectors and are predominantly maintained in a human-to-mosquito-to-human cycle. The *Aedes* species (*Ae. Aegypti* or *Ae. Albopictus*) which carries dengue have a much shorter flight span compared to the *Anopheles*. Additionally, the *Aedes* species are almost stationary and mostly prevalent in urban areas ([Garg, 2019](#)). Since gold mining typically occurs in rural areas, I do not expect there to be a discernible effect between gold mining and dengue.

to more cases of malaria. There are several reasons as to why we can expect there to be a link between gold mining and malaria, rather than a link between mining for other minerals and malaria. First, gold mining typically happens near rivers or bodies of water as well as demands water in the extraction process. Second, alluvial gold mining areas have more stagnant water surfaces, which provide an ideal breeding site for mosquitoes that transmit malaria. Third, gold mining typically happens on a much smaller scale and is therefore likely to happen near villages. Last, gold mining is likely to be performed in hard to reach places.

To investigate whether there is a link between other mining activities and malaria, this section maintains the same empirical structure as equation (1), but will test the effects of the MAP reform and other mineral activities such as copper, nickel, chromium, manganese and iron on the inverse hyperbolic sine of malaria cases. Figure 7 presents data on nickel, manganese, iron, gold, chromium and copper deposits throughout the Philippines, to further illustrate the geographic dispersion of mineral deposits. Table 4 then presents the results of the falsification tests, where I find no evidence that the presence of other mineral deposits after the MAP reform had an effect on the number of malaria cases relative to provinces without other mineral deposits.

### 5.3 Randomization inference

Last, I run a randomization inference analysis by randomly selecting 45 percent of the control provinces to receive the “treatment” of having a gold deposit and test whether the “treatment” has an effect on the incidence of malaria.<sup>12</sup> This analysis is similar to [Hoang et al. \(2020\)](#) and [Benshaul-Tolonen \(2019\)](#) and asks if there is a possibility that the effects shown in the main analysis are simply due to a “lucky draw” that is entirely unrelated to gold deposits. I randomly select half of the control provinces to receive the “treatment” status of having gold deposits, while the other half is assigned to be the “control”. I then replicate the DID regression from equation (1) using the falsified treatment and control groups. The randomization inference is run through 10,000 iterations and then the distributions of the estimated coefficients, their t-statistics and p-values are plotted in Figure 8. Each of the distributions for the estimated coefficients and t-statistics exhibit strong normal distributions centered around 0. In each of the panels, the red vertical line indicates the preferred estimation’s estimated coefficient, t-statistic and p-value obtained from column 4 in Table 2, respectively. Both the estimated coefficient and t-statistic are located in the right-tail of the distribution and indicate that the causal impacts estimated in Table 2 are not likely to be randomly generated.

---

<sup>12</sup>Given that 45 percent of the provinces in the Philippines have gold deposits, I opt for 45 percent in order to preserve the same real proportion.



## 6 Other potential mechanisms

The most likely mechanism at play is through the ecological response in which gold mining activities leave behind pools of water that provide the *Anopheles* mosquitoes with an environment to reproduce. This section investigates whether there are other possible mechanisms through which malaria may be exacerbated such as migration or deforestation.

### 6.1 Migration

Mining is often correlated with migratory behavior either through the labor-intensity that mining typically requires or through other commercial activities around the mines that attract migrants. Mining activities which often rely on highly mobile populations who migrate, are exposed to mosquito bites due to either long periods of time outdoors or through the living conditions in camps. Additionally, migration of previously unexposed populations to malaria into malaria endemic areas has often led to spikes in malaria cases, as well as returning migrants may introduce malaria parasites to new regions depending on the climate, activities and vector species present (Recht et al., 2017). Migrants can be further exposed to malaria as latent hosts, since they typically have lower incomes and less access to medical facilities (Garg, 2019). Mining operations are typically performed in rural areas and the settlement of these areas can make them more susceptible to outbreaks of malaria due to contact with settlers and vectors, and land clearing activities. Barbieri et al. (2005) show that after the initial stage of settlement, the prevalence of malaria declines for several reasons: 1) less interaction between humans and vectors; 2) the larger extent of cleared land; 3) improvements to housing conditions; 4) better access to health care; 5) greater personal resistance to malaria; and 6) greater knowledge about the disease.

To explore this hypothesis, the following equation is estimated:

$$Y_{p,t} = \beta_0 + \beta_1 MiningReform_t \cdot Gold_p + X'_{p,t} \cdot \delta + \rho_p + \tau_t + \epsilon_{p,t} \quad (3)$$

where  $Y_{p,t}$  is estimated separately for 1) the log of population; 2) share of population that migrated; 3) share of younger population who are between the ages of 15 and 49 that migrated to a given province; 4) share of population that migrated within a given province; 5) share of population who are miners that migrated; and 6) share of population who are miners that migrated within a given province  $p$  in year  $t$ . The focus on younger migrants is meant to address the concern that the majority of individuals migrating to work in the minerals and extractive sector are of a younger age. Table 5 presents the estimated results. In column 1 there is some evidence that after the reform, provinces with gold deposits experienced a corollary increase in population, but in columns 2 - 6 there is no evidence of a change in the population migrating, a change in intra-province migration or a change in miners who are migrating to or within provinces with gold deposits after the MAP reform.

## 6.2 Deforestation

Next, I explore a second mechanism that may explain the increase in malaria, which could be related to deforestation. One of the main negative externalities from mining is the loss of forest coverage. Deforestation has been linked to a wide variety of human activities including agriculture development, logging, transmigration programs, road, construction, mining and hydropower (Austin et al., 2019; Patz et al., 2000; Walsh et al., 1993). Gold mining can affect the ecosystem as it starts with vast deforestation (Recht et al., 2017), and more specifically through removing vegetation for mining pits, transportation access, and settlements (Alvarez-Berríos and Aide, 2015). Additionally, Indian districts with a higher proportion of small mines exhibit significantly greater deforestation per hectare (Baliatti et al., 2018), while in the Amazon, mining significantly increased deforestation up to 70km beyond the mining lease boundaries (Sonter et al., 2017).

Deforestation can alter the disease ecology of malaria in several ways. Cleared lands are generally more exposed to sunlight and prone to puddle formation with more neutral pH levels that can favor *Anophele* larvae development (Patz et al., 2000). A loss of biodiversity can also affect malaria incidence by reducing or eliminating species that prey on *Anophele* larvae and *Anopheles* mosquitoes (Laporta et al., 2013; Yasuoka and Levins, 2007). There is a long-standing literature linking deforestation with an alteration of the disease ecology of malaria (MacDonald and Mordecai, 2019; Tucker et al., 2017; Pattanayak and Pfaff, 2009; Keesing et al., 2010; Chakrabarti, 2018).<sup>13</sup> Garg (2019) provides the first causal estimates of the effect that forest loss has on the increased incidence of malaria in Indonesia. Additionally, Berazneva and Byker (2017) find similar evidence that the loss of forest coverage increased malaria incidence around 4.5 percent in children under five in Nigeria.

I investigate the deforestation channel through the following equation:

$$Deforestation_{p,t} = \beta_0 + \beta_1 MiningReform_t \cdot Gold_p + X'_{p,t} \cdot \delta + \rho_p + \tau_t + \epsilon_{p,t} \quad (4)$$

where  $Deforestation_{p,t}$  is the log of deforestation for a given province  $p$  in year  $t$ . Data on deforestation are derived from a satellite-generated forest cover database (Hansen et al., 2013), which provides global information about forest cover in 2000 and subsequent forest changes between 2001 and 2018.<sup>14</sup> Table 6 presents the results, where I find no evidence that provinces with gold deposits after the reform suffered more deforestation relative to provinces without gold deposits. Next I perform an event study similar to equation (2) to test whether there is an initial impact on deforestation immediately following the implementation of the MAP reform. Figure 9

<sup>13</sup>MacDonald and Mordecai (2019) document a bidirectional causal relationship where deforestation increases malaria through ecological mechanisms and malaria reduces deforestation through socioeconomic mechanisms.

<sup>14</sup>Landsat satellites capture pixel-level images with a 1 arc-second resolution, where GFC classifies forest cover and loss at a spatial resolution of 30 m x 30 m. The GFC defines forest cover as an area in which the biophysical presence of trees or vegetation higher than five meters accounts for more than 50 percent of the land and may take the form of natural forests or plantations over a range of canopy densities.

illustrates that there are no significant differences between treated and control provinces before and after the reform except for in years 2011, 2012, and 2015. The result additionally provides evidence that mining is likely to be small-scale in nature relative to open cast mining that involves the excavation of vast areas and the clearance of vegetation. Together this evidence suggests that there were no differential changes in forest coverage related to gold mining and the MAP reform, so we can rule out that the effect is running through the deforestation channel.

## 7 Conclusion

As the environment continues to be anthropogenically altered particularly in the form of land transformation and land clearance activities, there is likely to be an increase in the incidence of different diseases. This study improves our understanding of the relationship between natural-resource-policy and ecology by exploiting how a major shift in the Philippines' extraction policy to reduce the lag in granting mining permits had unintended health effects. More specifically, I provide causal evidence that provinces with gold deposits experienced 32 percent more malaria cases per 100,000 relative to provinces without gold deposits after the MAP reform. The main mechanism is argued to be through gold mining's creation of slow-moving bodies of stagnant water, which provide an ideal breeding site for *Anopheles* mosquitoes to propagate and reproduce. An event study approach estimates that the MAP reform had persistent effects on malaria 10 years beyond the implementation of the policy. Several falsification tests are performed, which reinforce the empirical strategy and suggest that the effect on malaria is specific to gold mining. An analysis of other possible mechanisms such as migration or deforestation provide no evidence of a statistical relationship, further supporting the ecological mechanism underpinning the relationship between malaria and gold mining.

There are nonetheless limitations to this work. One is that the analysis is performed at the provincial level and is attempting to measure local ecological effects. This limitation is due to the health reports providing data on malaria cases at the provincial level which could not be disaggregated to a more granular spatial unit. Using the province as the unit of analysis could potentially have an attenuating effect towards a lower bound on the main estimate. The falsification test results (based on different diseases and other mineral deposits) and various robustness tests provide credible arguments that gold mining is changing the ecology specific to malaria. However, there is certainly scope for further study of this topic. For instance, it would be interesting to explore whether the results hold in sub-Saharan Africa, other micro-climates or micro-habitats, and across countries with different environmental regulations.

Despite our understanding of how ecosystem transformation or degradation can affect human health, public policy needs to do more through environmental regulations or other tools to minimize unintended health effects in the context of mining expansion. Several different policies can be targeted to mitigate the incidence of malaria resulting from gold mining activities. First, clinics within gold mining communities can provide malaria specific information as to the transmission of malaria and proven anti-malarial interventions. Figure A.2 presents data

from the 2003 Demographic and Health Survey for the Philippines that indicates 80 percent of respondents know malaria comes from mosquitoes, while Figure A.3 suggests over 60 percent of respondents believe malaria is spread by mosquitoes. When asked the ways in which malaria can be prevented, the majority of respondents answered eliminate breeding places, followed by mosquito nets, spray house, other and avoid certain foods (Figure A.4). While there is a large portion of the surveyed population who understand where malaria comes from, the share drops substantially when asked about the transmission or methods of malaria prevention. Second, clinics within gold mining regions can provide specialized resources on proven anti-malarial interventions such as insecticide-treated bed nets, indoor residual spraying, or prompt clinical treatment as well as certain environmental management strategies such as drainage or canal linings. The third area for reform is related to mitigation efforts through monitoring and enforcement. This study suggests that the most likely mechanism leading to an increase in malaria is through the stagnant bodies of water that are left behind from gold mining activities. Monitoring compliance with proper mining protocols or rules may limit the stagnant water conditions needed for malaria to propagate and persist.

## References

- Acemoglu, D. and J. A. Robinson (2001). A theory of political transitions. *American Economic Review* 91(4), 938–963.
- Adhvaryu, A., J. Fenske, G. Khanna, and A. Nyshadham (2020). Resources, conflict, and economic development in africa. *Journal of Development Economics*, 102598.
- Alvarez-Berríos, N. L. and T. M. Aide (2015). Global demand for gold is another threat for tropical forests. *Environmental Research Letters* 10(1), 014006.
- Aragón, F. M. and J. P. Rud (2016). Polluting industries and agricultural productivity: Evidence from mining in ghana. *The Economic Journal* 126(597), 1980–2011.
- Arguin, P. and K. Tan (2017). Cdc yellow book: health information for international travel 2018.
- Austin, K. G., A. Schwantes, Y. Gu, and P. S. Kasibhatla (2019). What causes deforestation in indonesia? *Environmental Research Letters* 14(2), 024007.
- Balietti, A., L. Page, R. Pande, K. Rowe, and A. Sudarshan (2018). Lease splitting and dirty entrants: The unintended deforestation consequences of india’s environmental clearance process reform.
- Barbieri, A. F., D. Oya Sawyer, and B. S. Soares-Filho (2005). Population and land use effects on malaria prevalence in the southern brazilian amazon. *Human Ecology* 33(6), 847–874.
- Bauhoff, S. and J. Busch (2020). Does deforestation increase malaria prevalence? evidence from satellite data and health surveys. *World Development* 127, 104734.
- Bazillier, R. and V. Girard (2020). The gold digger and the machine. evidence on the distributive effect of the artisanal and industrial gold rushes in burkina faso. *Journal of Development Economics* 143, 102411.
- Beck-Johnson, L. M., W. A. Nelson, K. P. Paaajmans, A. F. Read, M. B. Thomas, and O. N. Bjørnstad (2013). The effect of temperature on anopheles mosquito population dynamics and the potential for malaria transmission. *PLOS one* 8(11), e79276.
- Bellemare, M. F. and C. J. Wichman (2020). Elasticities and the inverse hyperbolic sine transformation. *Oxford Bulletin of Economics and Statistics* 82(1), 50–61.
- Benshaul-Tolonen, A. (2019). Local industrial shocks and infant mortality. *The Economic Journal* 129(620), 1561–1592.
- Berazneva, J. and T. S. Byker (2017). Does forest loss increase human disease? evidence from nigeria. *American Economic Review* 107(5), 516–21.

- Berman, N., M. Couttenier, D. Rohner, and M. Thoenig (2017). This mine is mine! how minerals fuel conflicts in africa. *American Economic Review* 107(6), 1564–1610.
- Card, D. and S. DellaVigna (2020). What do editors maximize? evidence from four economics journals. *Review of Economics and Statistics* 102(1), 195–217.
- Caselli, F. and G. Michaels (2013). Do oil windfalls improve living standards? evidence from brazil. *American Economic Journal: Applied Economics* 5(1), 208–38.
- Caselli, F. and A. Tesei (2016). Resource windfalls, political regimes, and political stability. *Review of Economics and Statistics* 98(3), 573–590.
- Castellanos, A., P. Chaparro-Narváez, C. D. Morales-Plaza, A. Alzate, J. Padilla, M. Arévalo, and S. Herrera (2016). Malaria in gold-mining areas in colombia. *Memorias do Instituto Oswaldo Cruz* 111(1), 59–66.
- Chakrabarti, A. (2018). Deforestation, malaria and infant mortality in indonesia. *Available at SSRN 3257339*.
- Crompton, P., A. M. Ventura, J. M. De Souza, E. Santos, G. T. Strickland, and E. Silbergeld (2002). Assessment of mercury exposure and malaria in a brazilian amazon riverine community. *Environmental Research* 90(2), 69–75.
- Crost, B. and J. H. Felter (2020). Extractive resource policy and civil conflict: Evidence from mining reform in the philippines. *Journal of Development Economics* 144, 102443.
- Cruz, R., P. Lentejas, B. Gantioque, and E. Eizaguirre (2005). Improved investment climate in mining. Technical report, USAID.
- De Santi, V. P., R. Girod, M. Mura, A. Dia, S. Briolant, F. Djossou, I. Dusfour, A. Mendibil, F. Simon, X. Deparis, et al. (2016). Epidemiological and entomological studies of a malaria outbreak among french armed forces deployed at illegal gold mining sites reveal new aspects of the disease’s transmission in french guiana. *Malaria journal* 15(1), 1–11.
- Dube, O. and S. Naidu (2015). Bases, bullets, and ballots: The effect of us military aid on political conflict in colombia. *The Journal of Politics* 77(1), 249–267.
- Eggert, R. (2002). Mining and economic sustainability: National economies and local communities (london: International institute for environment and development).
- Eisler, R. (2004). Mercury hazards from gold mining to humans, plants, and animals. *Reviews of Environmental Contamination and Toxicology*, 139–198.
- Executive Order No. 270-A (2004, 01). National policy agenda on revitalizing mining in the philippines.



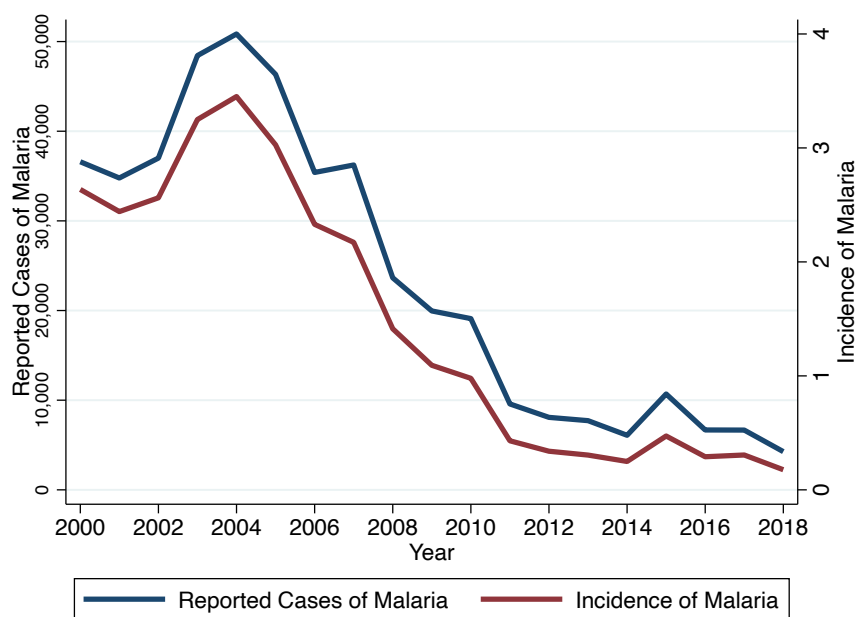
- Fong-Sam, Y. (2005). *The Mineral Industry of the Philippines*. U.S. Geological Survey, ed., 2005 Minerals Yearbook, U.S. Department of the Interior.
- Garg, T. (2019). Ecosystems and human health: the local benefits of forest cover in indonesia. *Journal of Environmental Economics and Management* 98, 102271.
- Gerson, J. R., N. Szponar, A. A. Zambrano, B. Bergquist, E. Broadbent, C. T. Driscoll, G. Erkenwick, D. C. Evers, L. E. Fernandez, H. Hsu-Kim, et al. (2022). Amazon forests capture high levels of atmospheric mercury pollution from artisanal gold mining. *Nature Communications* 13(1), 1–10.
- Gertler, P. J., S. Martinez, P. Premand, L. B. Rawlings, and C. M. Vermeersch (2016). *Impact evaluation in practice*. The World Bank.
- Gilles, H. M., D. A. Warrell, et al. (1996). *Bruce-Chwatt’s essential malariology*. Number Ed. 3. Edward Arnold (Publisher) Ltd.
- Greenstone, M. and B. K. Jack (2015). Envirodevonomics: A research agenda for an emerging field. *Journal of Economic Literature* 53(1), 5–42.
- Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. Turubanova, A. Tyukavina, D. Thau, S. Stehman, S. Goetz, T. R. Loveland, et al. (2013). High-resolution global maps of 21st-century forest cover change. *science* 342(6160), 850–853.
- Harris, I., T. J. Osborn, P. Jones, and D. Lister (2020). Version 4 of the cru ts monthly high-resolution gridded multivariate climate dataset. *Scientific data* 7(1), 1–18.
- Hedlund, U., B. Järholm, and B. Lundbäck (2006). Persistence of respiratory symptoms in ex-underground iron ore miners. *Occupational Medicine* 56(6), 380–385.
- Hoang, T. X., D. T. Le, H. M. Nguyen, and N. D. T. Vuong (2020). Labor market impacts and responses: The economic consequences of a marine environmental disaster. *Journal of Development Economics* 147, 102538.
- Imbahale, S. S., K. P. Paaijmans, W. R. Mukabana, R. Van Lammeren, A. K. Githeko, and W. Takken (2011). A longitudinal study on anopheles mosquito larval abundance in distinct geographical and environmental settings in western kenya. *Malaria Journal* 10(1), 81.
- Keesing, F., L. K. Belden, P. Daszak, A. Dobson, C. D. Harvell, R. D. Holt, P. Hudson, A. Jolles, K. E. Jones, C. E. Mitchell, et al. (2010). Impacts of biodiversity on the emergence and transmission of infectious diseases. *Nature* 468(7324), 647–652.
- Kiszewski, A., A. Mellinger, A. Spielman, P. Malaney, S. E. Sachs, and J. Sachs (2004). A global index representing the stability of malaria transmission. *The American journal of tropical medicine and hygiene* 70(5), 486–498.

- Laporta, G. Z., P. I. K. L. de Prado, R. A. Kraenkel, R. M. Coutinho, and M. A. M. Sallum (2013). Biodiversity can help prevent malaria outbreaks in tropical forests. *PLoS Negl Trop Dis* 7(3), e2139.
- MacDonald, A. J. and E. A. Mordecai (2019). Amazon deforestation drives malaria transmission, and malaria burden reduces forest clearing. *Proceedings of the National Academy of Sciences* 116(44), 22212–22218.
- Mitra, A. and D. Ray (2014). Implications of an economic theory of conflict: Hindu-muslim violence in india. *Journal of Political Economy* 122(4), 719–765.
- Mordecai, E. A., K. P. Paaijmans, L. R. Johnson, C. Balzer, T. Ben-Horin, E. de Moor, A. McNally, S. Pawar, S. J. Ryan, T. C. Smith, et al. (2013). Optimal temperature for malaria transmission is dramatically lower than previously predicted. *Ecology letters* 16(1), 22–30.
- Nunn, N. and N. Qian (2014). Us food aid and civil conflict. *American Economic Review* 104(6), 1630–66.
- Parham, P. E. and E. Michael (2010). Modeling the effects of weather and climate change on malaria transmission. *Environmental health perspectives* 118(5), 620–626.
- Parker, D. P., J. D. Foltz, and D. Elsea (2016). Unintended consequences of sanctions for human rights: Conflict minerals and infant mortality. *The Journal of Law and Economics* 59(4), 731–774.
- Pattanayak, S. K. and A. Pfaff (2009). Behavior, environment, and health in developing countries: evaluation and valuation. *Annu. Rev. Resour. Econ.* 1(1), 183–217.
- Pattanayak, S. K. and J. Yasuoka (2012). Deforestation and malaria: Revisiting the human ecology perspective. In *Human Health and Forests*, pp. 219–240. Routledge.
- Patz, J. A., T. K. Graczyk, N. Geller, and A. Y. Vittor (2000). Effects of environmental change on emerging parasitic diseases. *International Journal for Parasitology* 30(12-13), 1395–1405.
- Pavlova, P. and J. Hincks (2013). Mining in the philippines: Revisiting the rim. *Engineering and Mining Journal*, 64?74.
- Prüss-Üstün, A., S. Bonjour, and C. Corvalán (2008). The impact of the environment on health by country: a meta-synthesis. *Environmental Health* 7(1), 7.
- Recht, J., A. M. Siqueira, W. M. Monteiro, S. M. Herrera, S. Herrera, and M. V. Lacerda (2017). Malaria in brazil, colombia, peru and venezuela: current challenges in malaria control and elimination. *Malaria Journal* 16(1), 273.

- Republic Act 3573 (1929). Law on reporting of communicable diseases.
- Republic Act 7076 (1991, 06). An act creating a people's small-scale mining program, and for other purposes.
- Robinson, J. A., R. Torvik, and T. Verdier (2006). Political foundations of the resource curse. *Journal of Development Economics* 79(2), 447–468.
- Ross, M. and J. Murray (2004). Occupational respiratory disease in mining. *Occupational medicine* 54(5), 304–310.
- Rozo, S. V. (2020). Unintended effects of illegal economic activities: illegal gold mining and malaria. *World Development* 136, 105119.
- Sachs, J. D. (2003). Institutions don't rule: direct effects of geography on per capita income. Technical report, National Bureau of Economic Research.
- Service, M. W. and H. Townson (2002). The anopheles vector. In *Essential malariology*, pp. 59–84. CRC Press.
- Sinden, R. E. and H. M. Gilles (2002). The malaria parasites. *Essential malariology* 8, 34.
- Snow, R. W. and H. M. Gilles (2002). The epidemiology of malaria. *Essential malariology* 4, 85–106.
- Sonter, L. J., D. Herrera, D. J. Barrett, G. L. Galford, C. J. Moran, and B. S. Soares-Filho (2017). Mining drives extensive deforestation in the brazilian amazon. *Nature Communications* 8(1), 1–7.
- Soriano, M. and E. Makayan (2012). Review of collection and distribution of revenues from natural resources.
- Sunley, E. M., S. Caner, R. Krever, and O. Luca (2012). Reform of the fiscal regimes for mining and petroleum.
- Tewari, I. (2014). The distributive impacts of financial development: Evidence from mortgage markets during us bank branch deregulation. *American Economic Journal: Applied Economics* 6(4), 175–96.
- Texier, G., V. Machault, M. Barragti, J.-P. Boutin, and C. Rogier (2013). Environmental determinant of malaria cases among travellers. *Malaria Journal* 12(1), 87.
- Tucker, Lima, J. M., A. Vittor, S. Rifai, and D. Valle (2017). Does deforestation promote or inhibit malaria transmission in the amazon? a systematic literature review and critical appraisal of current evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences* 372(1722), 20160125.

- Uryu, Y., O. Malm, I. Thornton, I. Payne, and D. Cleary (2001). Mercury contamination of fish and its implications for other wildlife of the tapajós basin, brazilian amazon. *Conservation Biology* 15(2), 438–446.
- Valle, D. and J. M. T. Lima (2014). Large-scale drivers of malaria and priority areas for prevention and control in the brazilian amazon region using a novel multi-pathogen geospatial model. *Malaria Journal* 13(1), 1–13.
- Veiga, M. M., P. A. Maxson, and L. D. Hylander (2006). Origin and consumption of mercury in small-scale gold mining. *Journal of cleaner production* 14(3-4), 436–447.
- Verbrugge, B. (2014). Capital interests: A historical analysis of the transformation of small-scale gold mining in compostela valley province, southern philippines. *The Extractive Industries and Society* 1(1), 86–95.
- von der Goltz, J. and P. Barnwal (2019). Mines: The local wealth and health effects of mineral mining in developing countries. *Journal of Development Economics* 139, 1–16.
- Walsh, J., D. Molyneux, and M. Birley (1993). Deforestation: effects on vector-borne disease. *Parasitology* 106(S1), S55–S75.
- World Health Organization (1982). *Manual on environmental management for mosquito control, with special emphasis on malaria vectors*. World Health Organization.
- World Health Organization (2019). *World Malaria Report*. World Health Organization.
- Yasuoka, J. and R. Levins (2007). Impact of deforestation and agricultural development on anopheline ecology and malaria epidemiology. *The American Journal of Tropical Medicine and Hygiene* 76(3), 450–460.

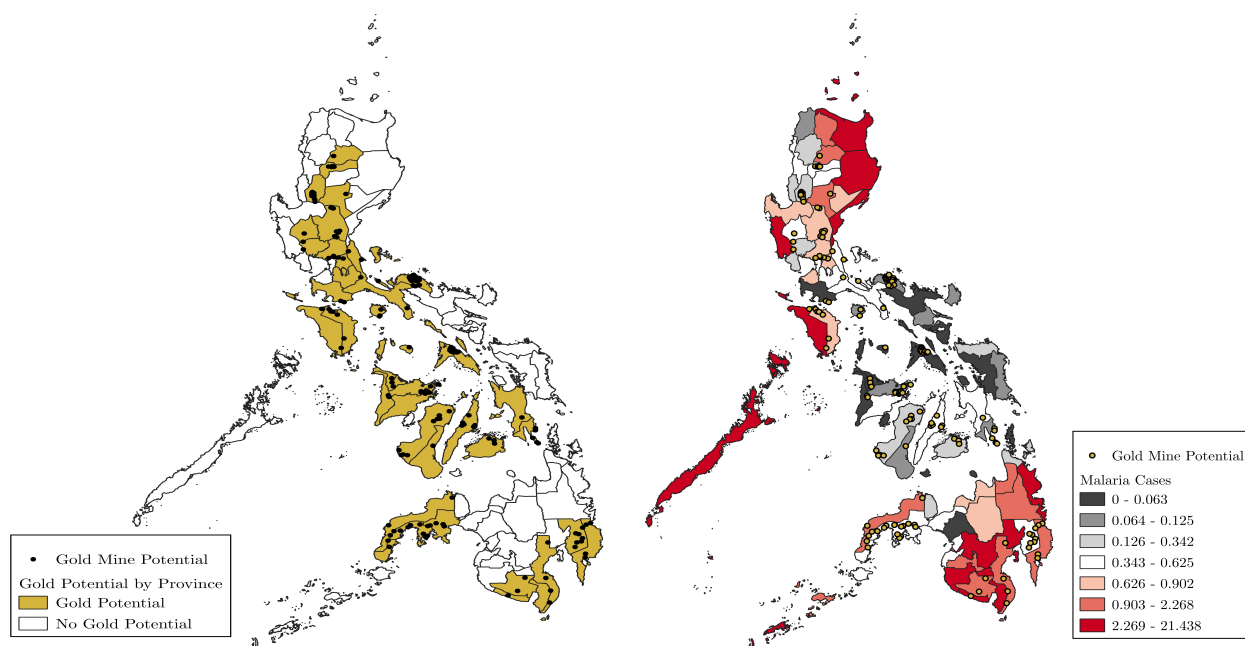
Figure 1: Reported cases and incidence of malaria in the Philippines, 2000 – 2018



*Notes:* This figure presents data on the number of reported cases of malaria and the incidence of malaria as the number of new cases of malaria in a year per 1,000 population at risk.

*Source:* World Development Indicators.

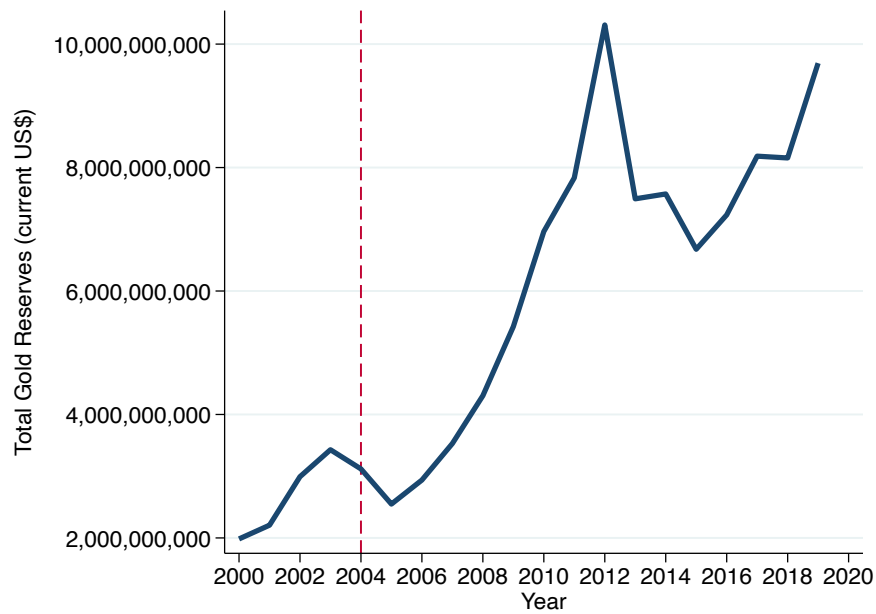
Figure 2: Identifying variation of gold deposits and average yearly number of malaria cases



*Notes:* The left panel presents the identifying variation, where provinces with gold deposits are shaded in yellow, while provinces without gold deposits are white. Each of the dots represent the potential for a gold mine. The right panel combines the two main data sources on malaria incidence and gold mine deposits. The map presents identifying variation, where the shaded provinces represent the average yearly number of malaria cases and the yellow dots represent gold mine potential. *Source:* Author's calculations using digitized mining maps from the MGB and health reports from the DOH.

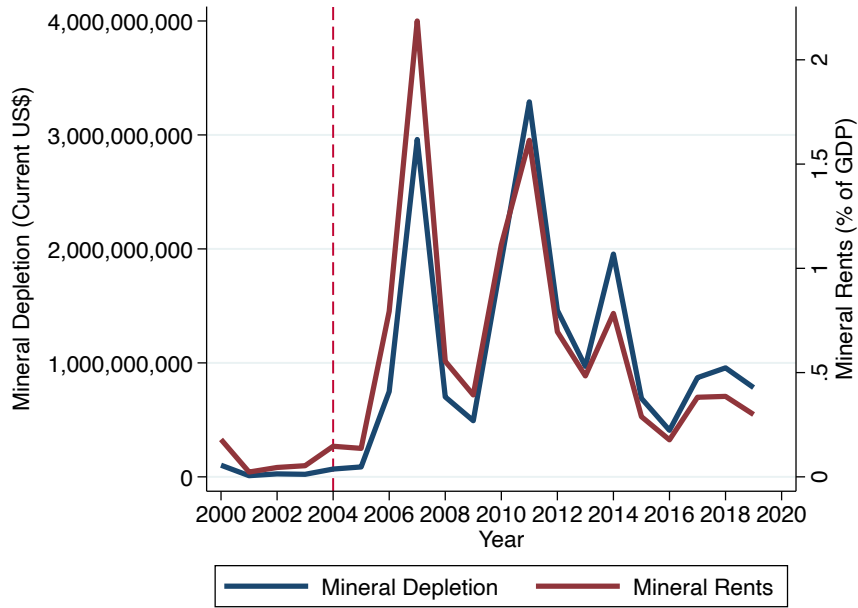


Figure 3: Total Gold Reserves



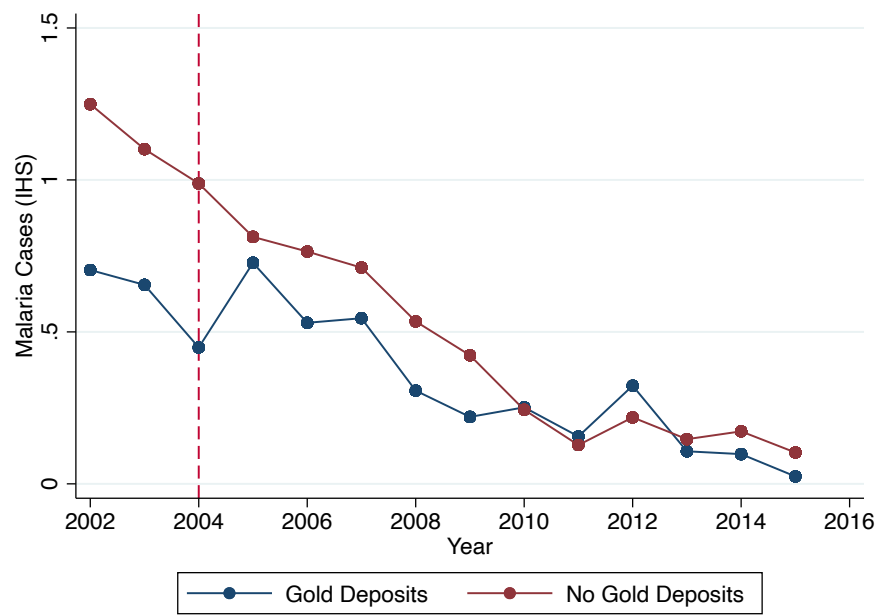
*Notes:* This figure presents data on the total reserves of gold in current US dollars. The time series is calculated by subtracting total reserves (with gold) minus total reserves (without gold) in order to disentangle the portion of total reserves that is gold. *Source:* Author's own calculations using data from World Development Indicators.

Figure 4: Mineral Depletion and Mineral Rents



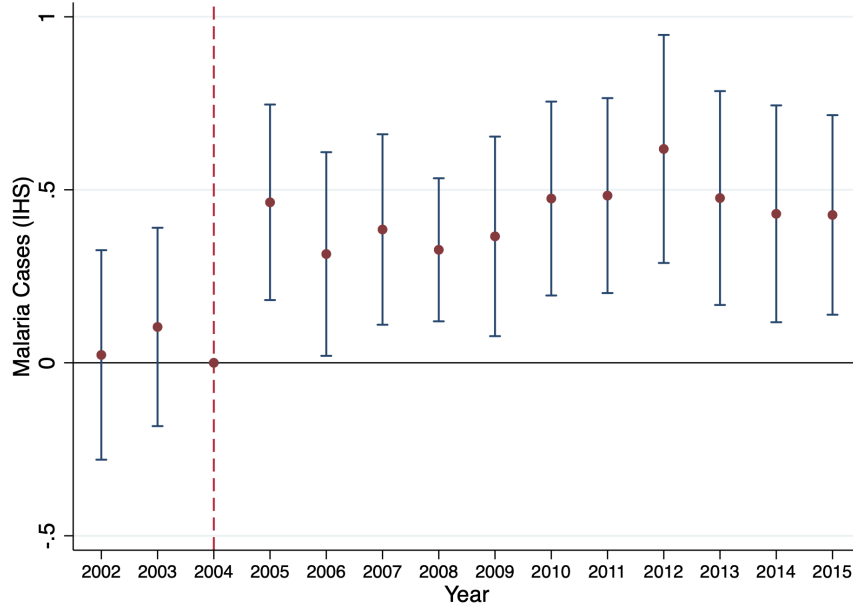
*Notes:* This figure presents data on mineral depletion in current US dollars and mineral rents as a percentage of GDP. Mineral depletion is the ratio of the value of the stock of mineral resources to the remaining reserve lifetime (capped at 25 years). Mineral rents are the difference between the value of production for a stock of minerals at world prices and their total cost of production. Minerals in both time series include tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate. *Source:* Author's own calculations using data from World Development Indicators.

Figure 5: Malaria cases by whether provinces have gold deposits



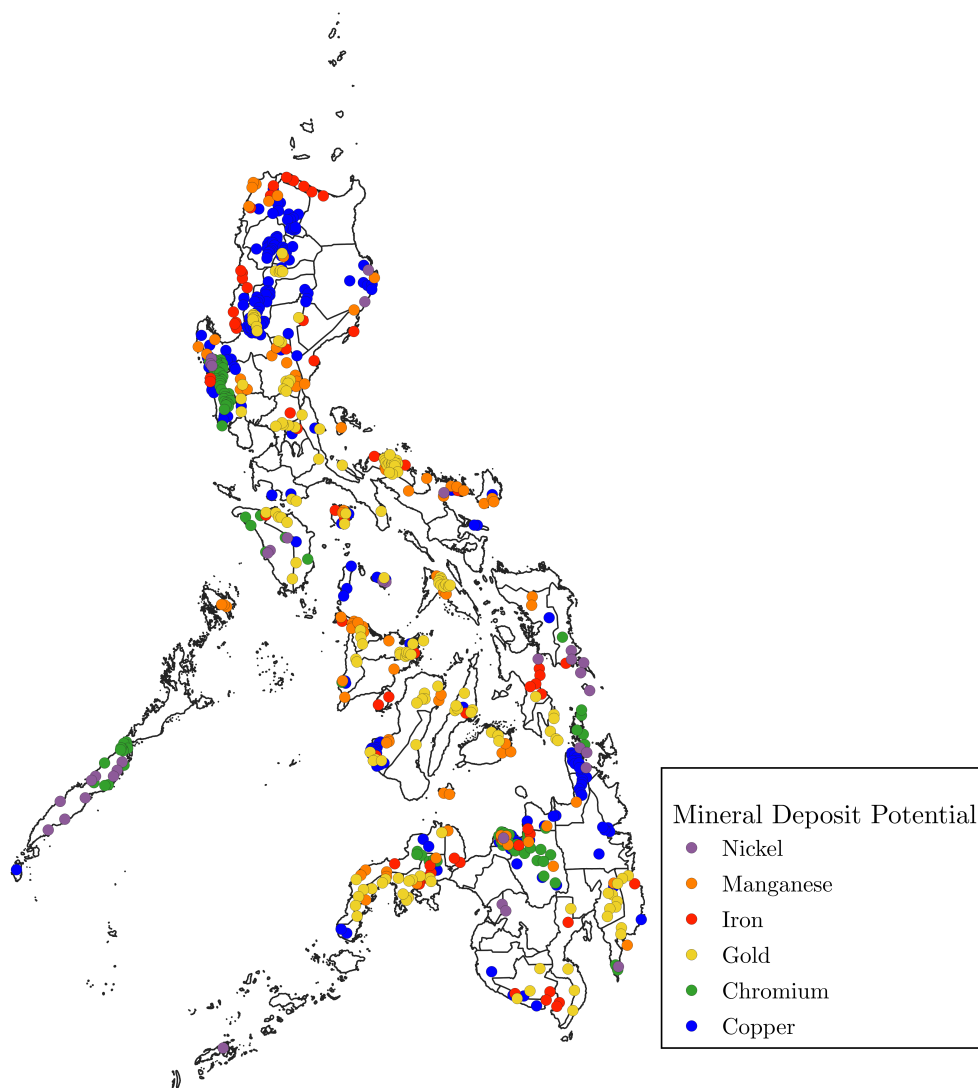
*Notes:* This figure displays parallel trends of malaria cases between provinces that have gold deposits and provinces that do not have gold deposits. *Source:* Author's own calculations.

Figure 6: Gold, MAP and the effect on malaria at the extensive margin, 2002 - 2015



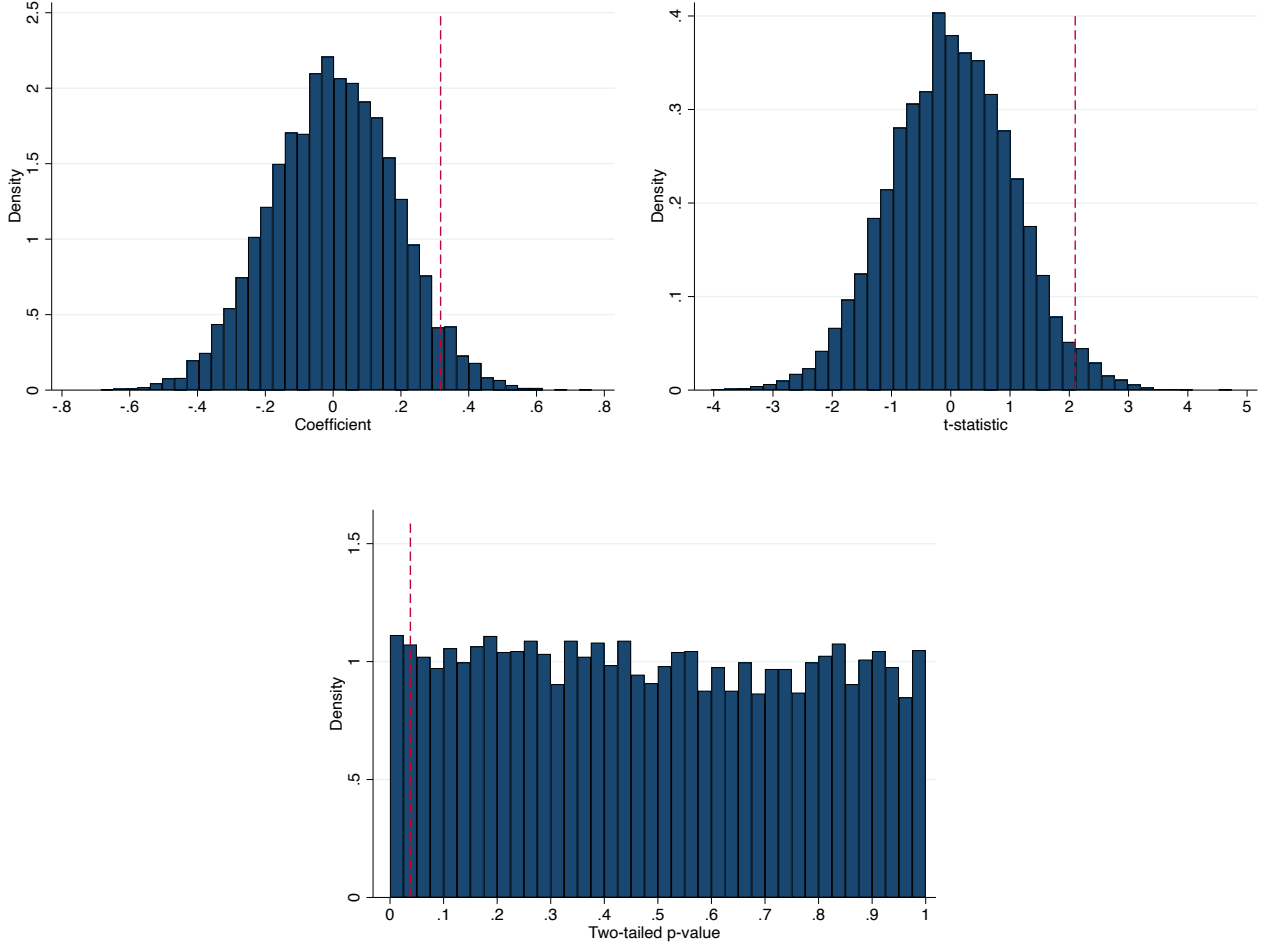
*Notes:* This figure presents estimates from an event study specification for the effect gold mining deposits have on the log of malaria cases for each year preceding and following the MAP reform. The year the MAP reform was implemented is omitted to make all estimates relative to this year. All treatment estimates are statistically insignificant prior to exposure to the reform. Immediately following the MAP reform, provinces with gold deposits experience 46 percent more malaria cases relative to provinces without gold deposits. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. The independent variables include: mean air temperature, mean precipitation, the poverty incidence level, log of population, log of deforestation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water.

Figure 7: Mineral deposits in the Philippines



*Notes:* This figure presents the geographical dispersion of mineral deposits throughout the Philippines, where each of the dots represent the potential for nickel, manganese, iron, gold, chromium, and copper deposits. *Source:* Author's calculations using mining maps from the Mines and Geosciences Bureau (MGB).

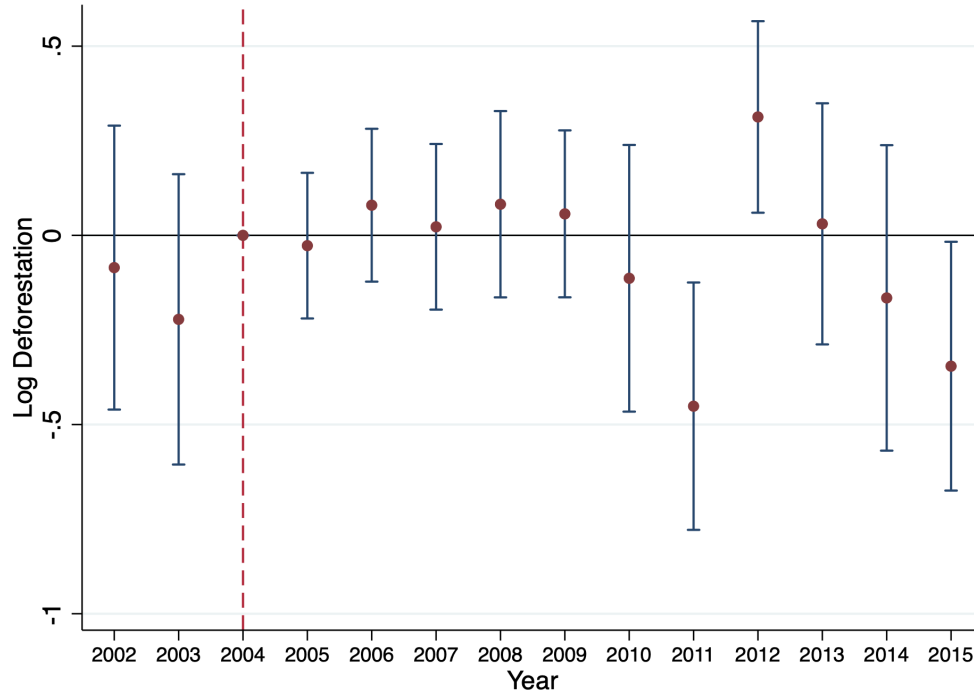
Figure 8: Distributions from permutation inference



*Notes:* These figures show the distribution of coefficients, t-statistics and p-values from a randomization inference where 45 percent of the control municipalities from the main analysis are randomly selected to either receive the “treatment” of having gold deposits or remain in the “control” of having no gold deposits. The permutation test is run through 10,000 iterations. The red line indicates the estimated coefficient (0.317), t-statistic (2.10) and p-value (0.038) obtained from column 4 of Table 1, respectively. The y-axis scales the height of the bars so that the sum of their areas equals 1. The independent variables include: poverty incidence level, log of population, log of deforestation, mean air temperature, mean precipitation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water.



Figure 9: Gold, MAP and the effect on Deforestation at the extensive margin, 2002 - 2015



*Notes:* This figure presents estimates from an event study specification for the effect gold mining deposits have on the log of deforestation for each year preceding and following the MAP reform. The year the MAP reform was implemented is omitted to make all estimates relative to this year. Following the reform, provinces with gold deposits are still statistically indistinguishable in terms of deforestation relative to provinces without gold deposits. In years 2011, 2012, and 2015 there appears to be statistical differences in terms of deforestation between provinces with gold deposits and provinces without gold deposits. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. The independent variables include: mean air temperature, mean precipitation, the poverty incidence level, log of population, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water.

Table 1: Balance test of covariates, 2000

	(1) Mean Air Tempera- ture	(2) Mean Pre- cipitation	(3) Poverty Incidence	(4) Log of Popula- tion	(5) Log of De- forestation	(6) Ethnic Frac- tionalization	(7) Religious Frac- tionalization	(8) Average Years of Education of the Household Head	(9) Fraction of Houses with Roofs Made of Strong Materials	(10) Fraction of Houses with Walls Made of Strong Materials	(11) Fraction of Houses with Access to Electricity	(12) Access to Indoor Toilet	(13) Access to Running Water
Gold	0.0601 (0.312)	-12.64 (8.891)	-1.891 (3.277)	0.426** (0.180)	0.151 (0.296)	-0.0257 (0.0604)	-0.000892 (0.0408)	0.108 (0.208)	0.0180 (0.0437)	-0.0499 (0.0359)	0.0424 (0.0399)	0.00609 (0.0372)	-0.00469 (0.0237)
Observations	79	79	79	79	79	79	79	79	79	79	79	79	79
R-squared	0.000	0.025	0.004	0.068	0.003	0.002	0.000	0.003	0.002	0.025	0.015	0.000	0.001

*Notes:* This table presents a balance test of covariates used in the analysis prior to the reform. Standard errors are clustered at the provincial level. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 2: Gold, MAP and the effect on malaria at the extensive margin, 2002 - 2015

	(1)	(2)	(3)	(4)
	Malaria Cases (IHS)	Malaria Cases (IHS)	Malaria Cases (IHS)	Malaria Cases (IHS)
Gold x Mining Reform	0.361** (0.158)	0.358** (0.159)	0.319** (0.144)	0.317** (0.145)
Observations	1,110	1,110	1,110	1,110
R-squared	0.244	0.246	0.317	0.317
Geographic Controls	No	Yes	No	Yes
Socioeconomic Controls	No	No	Yes	Yes
Mean Incidence	0.459	0.459	0.459	0.459

*Notes:* This table presents estimates for the effects that gold mining deposits have on the log of malaria cases, identified using a DID based on the timing of the MAP reform as well as the distribution of gold deposits. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. Geographic controls include: mean air temperature and mean precipitation. Socioeconomic controls include: the poverty incidence level, log of population, log of deforestation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 3: Gold, MAP and the effect on other diseases, 2002 - 2015

	(1) Dengue Cases (IHS)	(2) HIV Cases (IHS)	(3) Lower Respiratory Cases (IHS)	(4) Pneumonia Cases (IHS)	(5) Gastric or Duodenal Peptic Ulcer Cases (IHS)
Gold x Mining Reform	-0.0379 (0.153)	0.0883 (0.0596)	0.0189 (0.0656)	-0.0253 (0.0561)	-0.000250 (0.0573)
Observations	1,110	1,110	1,104	1,104	1,025
R-squared	0.375	0.230	0.211	0.265	0.194
Geographic Controls	Yes	Yes	Yes	Yes	Yes
Socioeconomic Controls	Yes	Yes	Yes	Yes	Yes
Mean Incidence	1.664	0.192	5.338	5.974	4.309

*Notes:* This table presents estimates for the effects that gold mining has on the inverse hyperbolic sine of Dengue, HIV, Lower Respiratory Infections, Pneumonia and Gastric or Duodenal Peptic Ulcer cases, identified using a DID based on the timing of the MAP reform as well as the distribution of gold deposits. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. The independent variables in columns 1-5 include: the poverty incidence level, log of population, log of deforestation, mean air temperature, mean precipitation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 4: Other types of minerals, MAP and the effect on malaria, 2002 - 2015

	(1)	(2)	(3)	(4)	(5)
	Malaria Cases (IHS)				
	Copper	Nickel	Chromium	Manganese	Iron
Mineral x Mining Reform	-0.00975 (0.157)	-0.0104 (0.208)	-0.0664 (0.168)	0.00381 (0.163)	0.00182 (0.169)
Observations	1,110	1,110	1,110	1,110	1,110
R-squared	0.310	0.310	0.310	0.310	0.310
Geographic Controls	Yes	Yes	Yes	Yes	Yes
Socioeconomic Controls	Yes	Yes	Yes	Yes	Yes
Mean Incidence	0.459	0.459	0.459	0.459	0.459

*Notes:* This table presents estimates for the effects other minerals have on the log of malaria cases, identified using a DID based on the timing of the MAP reform as well as the distribution of mineral deposits. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. The independent variables in columns 1-5 include: the poverty incidence level, log of population, log of deforestation, mean air temperature, mean precipitation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 5: Gold, MAP and the effect on population and migration, 2002 - 2015

	(1) Log Population	(2) Migration	(3) Youth Migration	(4) Intra-Province Migration	(5) Migrant Miners	(6) Intra-Province Migrant Miners
Gold x Mining Reform	0.0171* (0.00963)	-0.0265 (0.0895)	-0.0298 (0.0491)	-0.00207 (0.0406)	-0.000260 (0.00133)	-0.000814 (0.000764)
Observations	1,110	1,110	1,110	1,110	1,110	1,110
R-squared	0.816	0.505	0.504	0.336	0.349	0.353
Geographic Controls	Yes	Yes	Yes	Yes	Yes	Yes
Socioeconomic Controls	Yes	Yes	Yes	Yes	Yes	Yes
Dependent Mean	11.253	2.957	1.355	0.841	0.009	0.004

*Notes:* This table presents estimates for the effects that gold mining deposits have on the log of population, share of population that migrated, share of younger population that migrated, share of intra-province population that migrated, share of population who are miners that migrated, share of population who are miners that migrated within a province identified using a DID based on the timing of the MAP reform as well as the distribution of gold deposits. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. Geographic controls include: mean air temperature and mean precipitation. Socioeconomic controls include: the poverty incidence level, log of deforestation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Columns 2-6 additionally control for the log of population. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 6: Gold, MAP and deforestation, 2002 - 2015

	(1)	(2)	(3)	(4)
	Log Deforestation	Log Deforestation	Log Deforestation	Log Deforestation
Gold x Mining Reform	0.123 (0.169)	0.127 (0.168)	0.127 (0.171)	0.127 (0.171)
Observations	1,110	1,110	1,110	1,110
R-squared	0.274	0.275	0.291	0.291
Geographic Controls	No	Yes	No	Yes
Socioeconomic Controls	No	No	Yes	Yes
Mean Deforestation	15.162	15.162	15.162	15.162

*Notes:* Columns 1-4 present estimates for the effects that gold mining deposits have on the log of deforestation, identified using a DID based on the timing of the MAP reform as well as the distribution of gold deposits. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. Geographic controls include: mean air temperature and mean precipitation. Socioeconomic controls include: the poverty incidence level, log of population, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

# A Appendix

## A.1 Summary statistics

Table A.1: Summary statistics, 2002 - 2015

Dependent Variables	Observations	Mean	Std. Dev.	Min	Max
Malaria Cases	1,110	1.04	3.32	0.00	36.00
Malaria Cases (IHS)	1,110	0.46	0.82	0.00	4.28
Independent Variables					
Gold	1,110	0.45	0.50	0.00	1.00
Gold Deposits	1,110	1.88	3.08	0.00	17.00
Poverty Incidence	1,110	35.44	14.68	4.98	71.31
Log of Population	1,110	11.25	0.84	9.01	12.94
Log of Deforestation	1,110	15.16	1.56	6.80	19.13
Mean Air Temperature	1,110	25.97	1.31	21.10	28.00
Mean Precipitation	1,110	220.07	47.38	107.61	398.71
Ethnic Fractionalization	1,110	0.48	0.27	0.02	0.89
Religious Fractionalization	1,110	0.33	0.18	0.03	0.72
Average Years of Education of the Household Head	1,110	7.53	1.03	4.19	10.10
Fraction of Households with Roofs Made of Strong Materials	1,110	0.70	0.19	0.25	0.99
Fraction of Households with Walls Made of Strong Materials	1,110	0.73	0.15	0.25	0.99
Fraction of Households with Access to Electricity	1,110	0.66	0.19	0.16	0.97
Access to Running Water	1,110	0.43	0.17	0.11	0.98
Access to Indoor Toilet	1,110	0.89	0.10	0.53	1.00



## A.2 Additional results

Table A.2: Gold, MAP and the effect on malaria cases at the extensive margin, 2002 - 2015

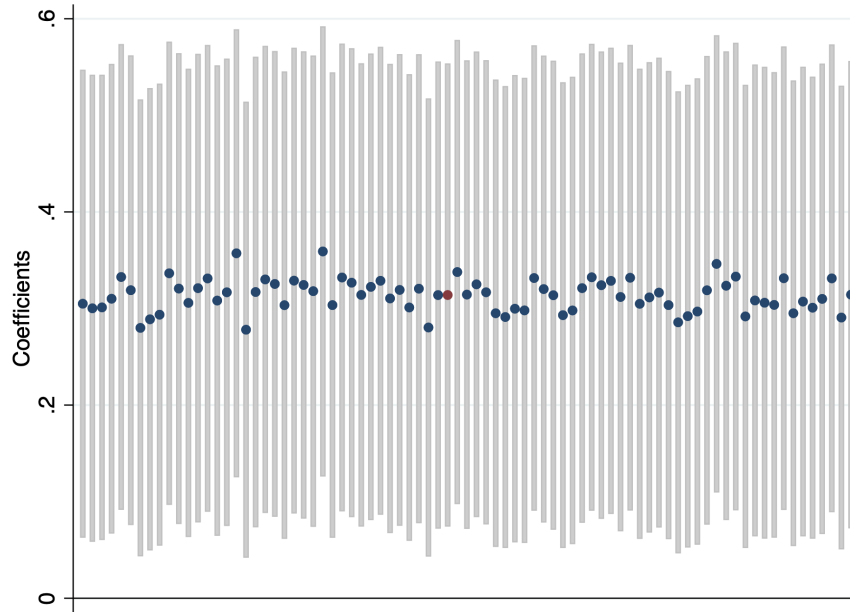
	(1)	(2)	(3)	(4)
	Malaria Cases	Malaria Cases	Malaria Cases	Malaria Cases
Gold x Mining Reform	2.257** (0.880)	2.265** (0.885)	2.270** (0.883)	2.276** (0.886)
Observations	1,110	1,110	1,110	1,110
R-squared	0.155	0.155	0.248	0.249
Geographic Controls	No	Yes	No	Yes
Socioeconomic Controls	No	No	Yes	Yes
Mean Incidence	1.038	1.038	1.038	1.038

*Notes:* This table presents estimates for the effects that gold mining deposits have on the absolute number of malaria cases, identified using a DID based on the timing of the MAP reform as well as the distribution of gold deposits. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. Geographic controls include: mean air temperature and mean precipitation. Socioeconomic controls include: the poverty incidence level, log of population, log of deforestation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

## A.3 Robustness tests

### A.3.1 Change of comparison groups

Figure A.1: Gold, MAP and the effect on malaria at the extensive margin, 2002 - 2015



*Notes:* This figure presents a robustness test that estimates the effects that gold mining deposits has on the log of malaria cases by dropping each province with gold deposits one at a time, identified using a DID based on the timing of the MAP reform as well as the distribution of gold deposits. This exercise illustrates the stability of the estimated coefficients and standard errors. The red coefficient is the point estimate obtained in Table 2, column 4. Each regression includes province and time fixed effects. Standard errors are clustered at the provincial level. The independent variables include: mean air temperature, mean precipitation, the poverty incidence level, log of population, log of deforestation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water.

### A.3.2 Controlling for health facilities

Table A.3: Controlling for health facilities, 2002 - 2015

	(1) Malaria Cases (IHS)	(2) Malaria Cases (IHS)	(3) Malaria Cases (IHS)	(4) Malaria Cases (IHS)
Gold x Mining Reform	0.337** (0.163)	0.332** (0.164)	0.297** (0.149)	0.293* (0.150)
Health Facilities x Mining Reform	0.00250 (0.00495)	0.00276 (0.00504)	0.00235 (0.00504)	0.00249 (0.00510)
Observations	1,110	1,110	1,110	1,110
R-squared	0.244	0.247	0.317	0.318
Geographic Controls	No	Yes	No	Yes
Socioeconomic Controls	No	No	Yes	Yes
Mean Incidence	0.459	0.459	0.459	0.459

*Notes:* This table presents a robustness test that additionally controls for the number of rural health facilities within each province. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. Geographic controls include: mean air temperature and mean precipitation. Socioeconomic controls include: the number of health facilities, the poverty incidence level, log of population, log of deforestation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

### A.3.3 Sensitivity to squared values of temperature and precipitation

Table A.4: Sensitivity to squared values of temperature and precipitation, 2002 - 2015

	(1) Malaria Cases (IHS)	(2) Malaria Cases (IHS)
Gold x Mining Reform	0.358** (0.157)	0.319** (0.143)
Observations	1,110	1,110
R-squared	0.250	0.320
Geographic Controls	Yes	Yes
Socioeconomic Controls	No	Yes
Mean Incidence	0.459	0.459

*Notes:* This table presents a robustness test that additionally controls for the squared terms of temperature and precipitation within each province. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. Geographic controls include: mean air temperature, mean air temperature squared, mean precipitation, and mean precipitation squared. Socioeconomic controls include: the poverty incidence level, log of population, log of deforestation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

### A.3.4 Controlling for quadratic time trends

Table A.5: Controlling for quadratic time trends, 2002 - 2015

	(1) Malaria Cases (IHS)	(2) Malaria Cases (IHS)	(3) Malaria Cases (IHS)	(4) Malaria Cases (IHS)
Gold x Mining Reform	0.312** (0.134)	0.310** (0.137)	0.325** (0.127)	0.320** (0.131)
Observations	1,110	1,110	1,110	1,110
R-squared	0.235	0.239	0.281	0.283
Geographic Controls	No	Yes	No	Yes
Socioeconomic Controls	No	No	Yes	Yes
Province-Trends	Quadratic	Quadratic	Quadratic	Quadratic
Mean Incidence	0.459	0.459	0.459	0.459

*Notes:* This table presents estimates for the effects that gold mining deposits have on the log of malaria cases, identified using a DID based on the timing of the MAP reform as well as the distribution of gold deposits. Standard errors are clustered at the provincial level. Each regression includes province fixed effects and quadratic time trends. Geographic controls include: mean air temperature and mean precipitation. Socioeconomic controls include: the poverty incidence level, log of population, log of deforestation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Significant at \*p < 0.10, \*\* p < 0.05, \*\*\* p < 0.01.

### A.3.5 Alternative transformation of the dependent variable

Table A.6: Alternative transformation of the dependent variable, 2002 - 2015

	(1) Log Malaria Cases	(2) Log Malaria Cases	(3) Log Malaria Cases	(4) Log Malaria Cases
Gold x Mining Reform	0.299** (0.125)	0.297** (0.127)	0.268** (0.114)	0.266** (0.115)
Observations	1,110	1,110	1,110	1,110
R-squared	0.244	0.246	0.319	0.319
Geographic Controls	No	Yes	No	Yes
Socioeconomic Controls	No	No	Yes	Yes
Mean Incidence	0.360	0.360	0.360	0.360

*Notes:* This table presents a robustness test that changes the definition of the dependent variable to  $\log(1 + \text{MalariaCases})$ . Each regression includes province and time fixed effects. Geographic controls include: mean air temperature and mean precipitation. Socioeconomic controls include: poverty incidence level, log of population, log of deforestation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

### A.3.6 Effect on malaria at the intensive margin

Table A.7: Gold, MAP and the effect on malaria at the intensive margin, 2002 - 2015

	(1) Malaria Cases (IHS)	(2) Malaria Cases (IHS)	(3) Malaria Cases (IHS)	(4) Malaria Cases (IHS)
Gold Deposits x Mining Reform	0.0316 (0.0204)	0.0310 (0.0209)	0.0231 (0.0196)	0.0221 (0.0198)
Observations	1,110	1,110	1,110	1,110
R-squared	0.237	0.239	0.311	0.313
Geographic Controls	No	Yes	No	Yes
Socioeconomic Controls	No	No	Yes	Yes
Mean Incidence	0.459	0.459	0.459	0.459

*Notes:* This table presents estimates for the effects that the number of gold mining deposits has on the log of malaria cases, identified using a DID based on the timing of the MAP reform as well as the distribution gold deposits. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. Geographic controls include: mean air temperature and mean precipitation. Socioeconomic controls include: the poverty incidence level, log of population, log of deforestation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A.8: Gold, MAP and the effect on malaria cases at the intensive margin, 2002 - 2015

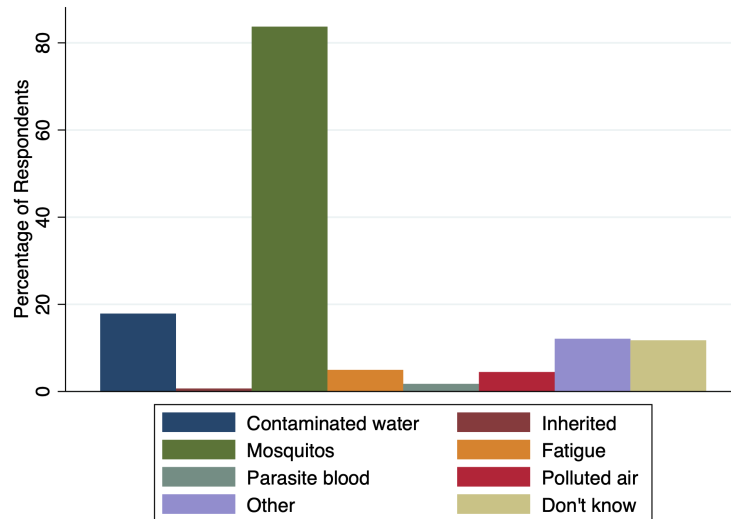
	(1) Malaria Cases	(2) Malaria Cases	(3) Malaria Cases	(4) Malaria Cases
Gold Deposits x Mining Reform	0.242** (0.108)	0.243** (0.108)	0.215** (0.104)	0.213** (0.102)
Observations	1,110	1,110	1,110	1,110
R-squared	0.140	0.140	0.230	0.240
Geographic Controls	No	Yes	No	Yes
Socioeconomic Controls	No	No	Yes	Yes
Mean Incidence	1.038	1.038	1.038	1.038

*Notes:* This table presents estimates for the effects that the number of gold mining deposits has on the absolute number of malaria cases, identified using a DID based on the timing of the MAP reform as well as the distribution gold deposits. Standard errors are clustered at the provincial level. Each regression includes province and time fixed effects. Geographic controls include: mean air temperature and mean precipitation. Socioeconomic controls include: the poverty incidence level, log of population, log of deforestation, ethnic fractionalization, religious fractionalization, average years of education of the household head, fraction of houses with roofs made of strong materials, fraction of houses with walls made of strong materials, fraction of households with access to electricity, access to indoor toilet and running water. Significant at \* $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .



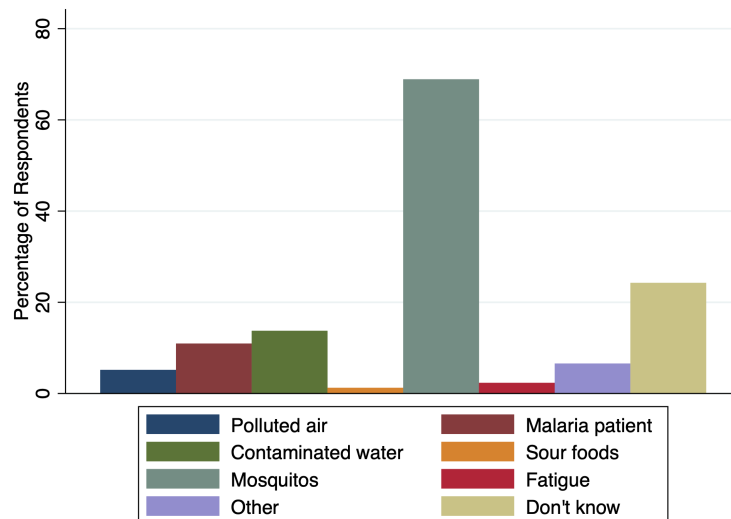
## A.4 Additional figures using demographic and health survey (DHS) data

Figure A.2: What causes malaria?



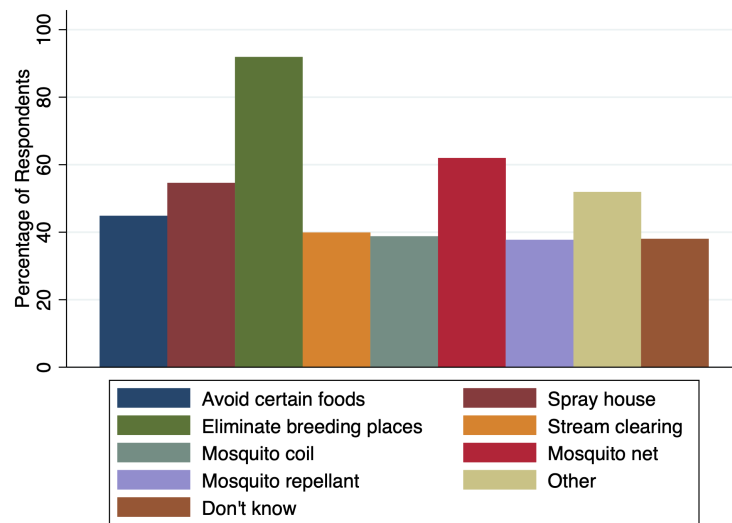
*Source:* Demographic and Health Survey (DHS) Data (2003)

Figure A.3: How is malaria spread?



*Source:* Demographic and Health Survey (DHS) Data (2003)

Figure A.4: Ways to prevent malaria



*Source:* Demographic and Health Survey (DHS) Data (2003)