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Article

"Bridging Knowledge to Policy"

The Impact of Borehole Provision on Rural Health and Economic Outcomes: The Case of Indonesia

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Abstract

Water is essential for daily economic activities. This study examines the impact of borehole water access on rural health and economy, focusing on reducing diarrhea and boosting small industries. Using data from PODES 2014-2021 and a 2019 borehole program, control villages with similar characteristics were selected. The sample includes 4,550 villages. DiD analysis show the policy does not significantly affect diarrhea prevalence or small industries. Boreholes may not meet all residents' needs, and factors like location and industrial suitability might reduce interest in using water for businesses.

Keywords: borehole wells; water access; diarrhea, small industries; micro industries.

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1. Introduction

Water is essential for daily economic activities, with increasing population and economic activities, the demand for water also increases. WHO states that developed countries require 60-120 liters of water per day; while developing countries such as Indonesia require 30-60 liters of water per day (Zora et al., 2022). Using poor quality water for drinking and bathing can cause health problems such as diarrhea. Poor water quality causes 3.4 million deaths each year worldwide, with diarrhea as the leading cause causing 1.4 million deaths (Berman, 2009). Diarrhea remains one of the leading causes of death for children and young children (UNICEF & WHO, 2015).

In Indonesia, access to clean water is still a major problem, especially in areas with diverse geological conditions. In rural areas, only about 60.5 percent of people have access to clean water and 47.84 percent have sanitation facilities (Alisjahbana et al., 2018). As many as 18 percent of households still use surface water that is vulnerable to contamination (BPS, 2014), often with substandard quality and unstable supply (Surjadi, 2003). Although most households boil their drinking water, 55 percent of drinking water samples remained contaminated with *fecal coliform* (Vollaard et al., 2004). Indonesia also has 54 million people practicing open defecation, increasing the risk of water pollution (UNICEF & WHO, 2015). Diarrhea is still a major health problem due to poor water quality and sanitation. According to Lawrence Green Theory, health behavior is influenced by predisposing factors (knowledge), enabling factors (facilities), and reinforcing factors (community support) (Notoatmodjo, 2014). Increasing public awareness about environmental health and improving water and sanitation infrastructure are essential for sustainable development (NIEHS, 2022).

Inequality in access to safe drinking water is thought to be a factor in the low Human Development Index (HDI) in Indonesia and Asia Pacific (Sukartini & Saleh, 2016; UN.ESCAP, 2007). Integration of water supply with micro-enterprises in water scarce and poor areas can improve this condition, especially for the poor. Micro-enterprise development should prioritize women because of their role in domestic water use and the economy (James et al., 2002; Noel et al., 2010). Household-based productive activities that utilize water, such as agriculture, animal husbandry, and micro-enterprises, are recognized as being of key importance to the poor. With minimal start-up costs, these activities provide economic opportunities to poor households, including those run by women, thus empowering them (Noel et al., 2010). Empowerment of the poor, especially in rural areas, involves two types of change: improving the environment by providing essential services/infrastructure and increasing the ability of individuals to improve their own circumstances (Batten, 1974). The United Nations defines community development as the process by which self-help efforts of communities are combined with government efforts to improve the economic, social, and cultural conditions of communities, to integrate communities into the life of the nation, and to provide opportunities for communities to contribute fully to the progress of the nation (Nasdian, 2014).

To address this issue, the government has set a target in the 2020-2024 National Medium-Term Development Plan (RPJMN) to achieve universal access to clean water and sanitation by 2030 following the Sustainable Development Goals (SDGs). One strategy relied on is the borehole construction program in areas with limited surface water sources. This program not only supports access to clean water but also has the potential to increase economic productivity by developing small and micro industries that depend on adequate water supply. Government intervention is needed to provide access to clean water to the community equally, especially in water-scarce areas. Differences in geological conditions, particularly rainfall variability and hydrology in some parts of Indonesia, are often an obstacle for residents in obtaining clean water. Clean water is a human right that must be guaranteed by the state to all its people. (Mungkasa, 2006). To ensure its availability, the Ministry of Energy and Mineral Resources supports the development of energy infrastructure through the provision of groundwater boreholes, using funds from the State Budget. (KESDM, 2018, 2019b).

The construction of boreholes is focused mainly on areas experiencing water crisis and underdeveloped areas. It is expected that the clean water supply will support the acceleration of infrastructure development in these locations, which is in line with the mission of the Ministry of Energy and Mineral Resources in carrying out Equitable Energy. Technical specifications of the borehole depth of about 125 meters, water discharge between 1.50 to 2.30 liters per second with electricity supply from a generator with a capacity of 12.5 kVA using a 3 PK *submersible* pump and equipped with a generator house, pump house and water reservoir with a capacity of 5000 liters. (KESDM, 2019a). This program has been ongoing since 2005 and since 2021 the development authority has been transferred from KESDM to the Ministry of Public Works and Public Housing (PUPR), The construction, revitalization and repair of boreholes that have been built are still continuing until now. The Geological Agency of the Ministry of Energy and Mineral Resources has built 3,475 clean water boreholes throughout Indonesia by the end of 2020. (KESDM, 2023).

This reflects that the government has made efforts to overcome the water crisis by increasing access to clean water in several areas. Based on the theoretical and literature review, the construction of boreholes in addition to providing access to clean water has the potential to produce other derivative *outcomes* such as improved health quality and increased economic activities in the form of an increase in the number of small and micro industries and business opportunities. For this reason, the question arises whether providing access to clean water to these areas is sufficient and whether there are other impacts, such as on the quality of health and economic activities of the community. This study therefore aims to provide empirical evidence on the extent of the impact of groundwater borehole development on the quality of health and economic activities of communities in rural areas that are generally relatively poorer, this is in line with the sustainable development goal of rural community welfare, which supports the achievement of SDG 3 (good health and well-being), SDG 6 (clean water and proper sanitation), and SDG 8 (decent work and economic growth). This study focuses on two aspects, namely First, measuring the impact on villages that experience clean water difficulties before and after having communal boreholes managed by local communities can have an impact on improving the quality of health, which in this study is proxied by a decrease in the prevalence of diarrhea sufferers (Adams, 2015; Devoto et al., 2015). (Adams, 2015; Devoto et al., 2012; Esrey et al., 1988; Komarulzaman et al., 2017; Patunru, 2015; Tonglet et al., 1992; Usman et al., 2019; Wang et al., 1989; Wapenaar & Kollamparambil, 2019).. Second, measuring the impact on villages experiencing clean water difficulties before and after having a communal borehole managed by the local community can have an impact on improving economic activities through efficiency, productivity and business opportunities which in this study are proxied by an increase in the percentage of small and micro industries in recipient villages that most of their production activities use water, namely the pottery/ceramic/stone industry (Boelee et al., 2019). (Boelee et al., 1999) and the food and beverage industry (Moriarty et al., 2004; Noel et al., 2010; Sefiani & Bown, 2013). to the number of households (Nisa & Riyanto, 2022).

The references used in this study are highly relevant and remain indispensable as they cover a wide range of important aspects. Seminal studies such as Esrey et al. (1988), Wang et al. (1989), and Tonglet et al. (1992) laid the foundation for understanding the relationship between access to clean water and reduced diarrhea prevalence, with empirical validity that remains pertinent today. In the Indonesian context, studies by Komarulzaman et al. (2017), Patunru (2015), and Usman et al. (2019) provide localized evidence of the impact of clean water access on public health and well-being, which is crucial given the country's unique conditions. On the economic side, studies such as Boelee et al. (1999), Moriarty et al. (2004), and Noel et al. (2010) highlight the role of clean water in supporting small and micro industries that rely on a stable water supply. Furthermore, the quantitative methodological approaches employed by Adams (2015) and Wapenaar & Kollamparambil (2019) serve as robust models for impact analysis in this study. The combination of both older and newer references underscores the continuity of the literature, providing a solid scientific and contextual foundation for addressing this researh question.

Many households in Indonesia still rely on unsafe drinking water sources, such as wells and rivers that are prone to microbial contamination. This contamination occurs at various stages, including collection and storage (Shaheed et al., 2014). Access to clean water has a positive impact on economic growth, the Human Development Index (HDI), and reduces disease, especially if supported by adequate sanitation infrastructure (Sukartini & Saleh, 2016). Research in Nigeria shows that increased access to clean water is associated with health improvements, such as a reduction in infant mortality from 6.7 percent to 2.8 percent (Rosen & Vincent, 1999). Studies in Indonesia, using Susenas and DHS data, found that the prevalence of diarrhea was more related to poor environmental sanitation than low access to clean water (Patunru, 2015; Komarulzaman et al., 2017). Indonesian Family Life Survey data shows that access to basic household sanitation reduces the risk of health complications during pregnancy (Cameron et al., 2021). Another study found that the absence of improved toilets in households increases the risk of diarrhea and mortality of children under five (Semba et al., 2011). Boreholes and easy access to water have been shown to have a positive impact on household health, reducing the risk of disease due to poor water quality. This study aims to add insight into village health, particularly diarrheal disease, hypothesizing that the borehole program has an impact on diarrhea prevalence.

In terms of economics, related research conducted in Nicaragua shows that the ability to generate income from rope pump wells has been an important reason for acceptance and successful introduction (Alberts, 2003). (Alberts, 2003). Appropriate technology is needed to meet the demand for quality and productive water. Multipurpose water supply systems are considered to alleviate poverty by improving health and income through increased production (Mendiguren, 2004). Research in India shows that increasing household water supply can reduce poverty by increasing rural incomes and business opportunities. Integration of water supply with micro-enterprises, especially in water scarce and poor areas, can realize economic benefits. (James et al., 2002).

In Indonesia, research related to water access with business opportunities, productivity and the number of small and micro industries is still very limited, the scope of existing research is limited to HDI and life expectancy. Among other things, improving access to water and sanitation has a positive impact on health and life expectancy, and improves welfare by reducing disease (Kustanto, 2015). In Surabaya, limited access to clean water and poor water quality reduces productivity and causes large annual losses due to diarrhea (Triono, 2018). Other studies have shown that increased access to clean water and improved sanitation reduce disease and increase the Human Development Index (HDI), and that allocating funds for infrastructure can increase GRDP and reduce poverty (Sukartini & Saleh, 2016). The literature concludes that boreholes and easy access to water have a positive impact on households, especially in expenditure as they do not require operational costs. Previous research shows that boreholes and irrigation systems increase household expenditure efficiency as well as community productivity. Although there is no firm research on the economic impact of boreholes at the village level, the literature implies that small-scale water access can increase economic activity. Based on previous studies, it is hypothesized that the borehole program has an impact on village economic activities, especially small water-using industries, such as pottery, ceramics, stone, and food and beverage industries.

This study uses borehole distribution data from KESDM and PODES data from 2014, 2018, 2019, 2020, and 2021. KESDM reported that from 2005-2020, 3,475 boreholes were constructed in 1,864 sub-districts, 396 districts, and 35 provinces. The year 2019 was chosen because it had the largest number of boreholes, with data from 2014 and 2018 as the *pre-treatment* period and 2020 and 2021 as the *post-treatment* period to capture short-term impacts. Limitations of the PODES data, such as the absence of population size, prevalence of certain diseases, and expenditure or income data, were addressed by using the number of households using electricity as a proxy for population. Data prior to 2014 was not used due to inconsistencies in data on the number of diarrhea cases and small industries. The use of the number of households using electricity as a proxy for population, while providing a rough estimate, has the potential to obscure more specific population variations, such as demographic structure and income distribution. In addition, inconsistencies in data on diarrhea cases and small industries before 2014 limit the ability to evaluate long-term trends, resulting in findings that focus more on the short-term impacts of post-borehole construction. This study uses borehole construction data from KESDM and a *difference-in-differences* (DID) approach to analyze their impact in reducing diarrhea prevalence and increasing the number of small industries in rural Indonesia. Although the DID approach used can address some biases, these data limitations remain a factor that may affect the generalizability and external validity of the results. Villages with boreholes were analyzed as the treatment group, while villages without boreholes but with access to clean water difficulties and located in the same sub-district as the control group, in order to equalize village characteristics. This study measures the effect of borehole construction on reducing diarrhea prevalence and increasing the percentage of small industries by comparing *treatment* and *control* villages before and after the borehole construction policy.

Based on the estimation results, the borehole program has no impact on the prevalence of diarrhea. This result is different from studies (Esrey et al., 1988; Tonglet et al., 1992; Wang et al., 1989) which found a significant correlation between access to clean water and diarrhea, but in line with (Adams, 2015; Devoto et al., 2012) which found no significant impact. The borehole program also had no impact on the percentage of small industries. This result is in contrast to (Boelee & Laamrani, 2004; James et al., 2002; Jehangir et al., 1998; Mendiguren, 2004) who found a significant correlation, but in line with (Davis et al., 2001) who found no significant impact. Tests in Java and outside Java also show similar results, with no significant impact of water access through boreholes on diarrhea prevalence and percentage of small industries.

2. Literature Review

The groundwater borehole program funded by the State Budget through the Ministry of Energy and Mineral Resources aims to improve clean water infrastructure in water crisis areas with predetermined technical specifications. Each borehole has a depth of about 125 meters, a water discharge of 1.50-2.30 liters per second, and uses electricity from a 12.5 kVA generator with a 3 PK submersible pump, equipped with a generator house, pump house, and water reservoir with a capacity of 5,000 liters. With these specifications, each borehole unit is estimated to be able to serve the clean water needs of up to 2,160 people (KESDM Geological Agency, 2019b, 2019a). The determination of borehole locations is based on geo-electrical tests and placement in areas with good groundwater aquifers, such as mountainous areas with permeable rock formations, geological basins with sedimentary deposits near lakes or rivers, and lowlands with sand, gravel and limestone deposits (Todd, 1980). This program has been ongoing since 2005 and is currently managed by the Ministry of PUPR since 2021. Local governments are responsible for the repair and maintenance of boreholes that have been built by the Geological Agency of the Ministry of Energy and Mineral Resources. As of the end of 2020, the program has successfully built 3,475 borehole units spread across 1,864 sub-districts, 396 districts, and 35 provinces throughout Indonesia.

Environmental Health is a field within public health that examines the impact of the physical, chemical, biological, and social environments on human health, with the goal of improving people's health and well-being and creating health-supportive environments. Efforts in environmental health include evaluating environmental factors to prevent disease, manage risk, and promote healthy environments (The National Environmental Health Partnership Council, 2014; Lee, 2019). Environmental health is an integral part of the public health system that works to reduce exposure to chemicals and other pollutants in air, water, soil, and food, and advances policies to protect overall public health (The National Environmental Health Partnership Council, 2014). Efforts to create healthy environments are also a key strategy in sustainable development, with a focus on improving environmental quality for populations vulnerable to the impacts of environmental diseases (NIEHS, 2022). Access to clean and safe drinking water and sanitation is crucial for maintaining optimal environmental health. Boreholes are a government initiative to improve access to clean water, which is more reliable and sustainable than surface water. However, the quality of water from boreholes can be affected by infrastructure factors and individual health behaviors before consumption, which can have a negative impact especially on children. In Lawrence Green's basic theory, predisposing (knowledge), enabling (facilities), and reinforcing (community support) factors are identified as the main determinants of individual health behavior (Notoatmodjo, 2014).

Several studies have shown that adequate access to clean water plays an important role in reducing the incidence of diseases such as diarrhea. A World Bank study in Paraguay involving 122,000 poor households found that areas with access to clean water had an almost 7-fold lower reduction in diarrhea outbreaks compared to areas without access to clean water (Klees et al., 2016). In Romania, a study with 1,600 households showed significant improvements in infant health indicators after gaining access to clean water (Skoufias, 1998).

In addition, good sanitation such as hand washing and safe water management are essential to prevent diarrheal diseases, especially in areas with limited sanitation infrastructure (Haggerty et al., 1994; Cairncross et al., 2010; Hill et al., 2004; Luby et al., 2005; Kumar & Vollmer, 2013). Borehole development programs, such as the one conducted by KESDM with the installation of generators and storage tanks, have been shown to reduce diarrhea cases in Bolivia during the summer (Quick et al., 1999; Aluoch et al., 2008). Water treatment at the point of use (POU), safe water storage, and proper water handling can also reduce the risk of exposure to waterborne pathogens (Arnold & Colford, 2007; Clasen et al., 2007; Günther & Schipper, 2013).Infrastructure development such as boreholes not only increases access to clean water, but also helps improve the quality of life of people in remote areas by reducing water collection time and increasing water availability for daily needs (Cairncross, 1987; Cairncross, 1997; Curtis et al., 2000; Sorenson et al., 2011). In general, based on the theoretical and literature review above, the borehole program has the potential to have a positive impact on public health by reducing the risk of diseases caused by poor water quality, such as diarrhoeal diseases. This study underscores the importance of improving access to clean water to maintain environmental health, especially in rural areas that still face challenges in sanitation and water access.

Water is crucial in terms of its quality and quantity. Many rural communities still depend on agriculture and small/micro enterprises for livelihoods, where water supply plays a critical role. Providing water supply to households has great potential to reduce poverty, especially among the vulnerable poor and women. New efforts include sustainable development, participatory approaches, and integrated communal water resources management, focusing on small-scale productive water uses such as agriculture and small businesses within a local community. Empowerment of the poor, especially in rural areas, is one of the efforts that need to be done, in the theory of community development efforts to improve the condition of the local community through two types of changes, namely improving the environment by providing essential services/infrastructure and increasing the ability of individuals to improve their own situation. (Batten, 1974). The United Nations defines community development as a process in which all community self-help efforts are combined with local government efforts to improve community conditions in the economic, social, and cultural fields and to integrate the community into the life of the nation, state and provide opportunities for the community to fully contribute to the progress of the nation (Nasdian, 2014). (Nasdian, 2014).

The provision of boreholes by the government is an important step to improve access to clean water that is more reliable and sustainable than surface water. It is expected to improve community circumstances by providing clean water infrastructure that enables environmental improvements and improved economic conditions. Several studies have shown that boreholes contribute to water use efficiency, increase productivity, and open up new business opportunities for local communities. In Zimbabwe, improved water access from wells shifted the responsibility of watering gardens from women and children to men, allowing women to focus on marketing crops (Proudfoot, 2003). In Masvingo Province, use of water from collector wells increased community garden production with a financial return of US$38.00 per member during the winter season (Waughray et al., 1998). In Syria, well water supports agriculture, contributing to family diets and income (Waughray & Rodriguez, 1998). Boreholes support village irrigation systems, increasing agricultural productivity and maintaining sustainability amidst climate change (Bakker et al., 1999;

Fernando & Halwart, 2000; Nguyen-Khoa et al., 2005). The use of borehole water also increases dietary diversity and family income in areas with limited surface water sources (Meinzen-Dick, 1997). In general, based on the theoretical and literature review above, boreholes have a positive impact on households by improving water use efficiency and economic productivity, especially in the small industry sector that uses water as a key production factor. Although there is no in-depth research on the direct impact of boreholes on village economies, the literature suggests that adequate access to water can increase economic activity.

3. Methods

Impact evaluations are necessary to ensure the effectiveness of government programs and improve accountability of resource allocation (Khandker et al., 2010). It is important to distinguish between successful and unsuccessful programs and measure their impact on welfare based on program design, target achievement, and implementation (Gertler et al., 2016). Impact evaluation is also part of the evaluation approach that supports evidence-based policy, which involves monitoring and evaluation activities. The *Difference in Difference* (DID) method is an appropriate approach to evaluate the impact of a policy or program, especially in the construction of boreholes. This method is often used to compare conditions before and after policy implementation (Stuart et al., 2014). Therefore, this study uses the DID method to evaluate the impact of the borehole construction program in the village on the prevalence of diarrhea as a proxy for health quality, as well as on the percentage of small and micro industries in the village whose production activities use water, such as pottery, ceramics, stone, food, and beverage industries (Moriarty et al., 2004; Noel et al., 2010; Sefiani & Bown, 2013).The DID method allows measuring the net effect of a policy by comparing the average change in outcomes between the treatment group and the control group, making it a popular policy evaluation tool (Gultom, 2019).

Prevalence is the proportion of the population that has a certain characteristic in a certain period of time, often used in medicine to describe diseases or risk factors. Prevalence measurement can be done in several ways that vary according to the time frame of estimation. The first way is point prevalence, which is the proportion of the population that has a characteristic at a certain point in time. The second way is period prevalence, which is the proportion of the population that has a certain characteristic in a certain period of time, usually 12 months (Bonita et al., 2006). The prevalence of diarrhea in this study was measured by Equation (1).

$$Y_{it}^{1} = \frac{Jumlah\ Penderita\ Diare\ Setahun\ terakhir_{it}}{Jumlah\ penduduk_{it}} \quad (1)$$

With Y_{it}^{1} is the calculation for the dependent variable (Y^{1}) is the prevalence of Diarrhea disease in village i in the period of year t, which is calculated from the number of Diarrhea Patients recorded in village i in the period of year t divided by The total population in village i in the period of year t. Due to the inconsistency of PODES data in providing population data in certain years, the number of people for whom there is no data will use the number of households using PLN, Non PLN and non-users of Electricity which is sufficient to represent the number of all heads of households in village i in the period of year t and multiplied by the average family members of the district in village i in the period of year t.

In addition to the prevalence of diarrhea based on the theoretical basis and literature, this study also conducted a DID regression to see the impact analysis of the borehole construction program in increasing village economic activities, which in this study is proxied by an increase in the percentage of small and micro industries in recipient villages that mostly use water for production activities, namely the pottery/ceramic/stone/food and beverage industries (Moriarty et al., 2004; Noel et al., 2010; Sefiani & Bown, 2013). (Moriarty et al., 2004; Noel et al., 2010; Sefiani & Bown, 2013) to the number of households (Nisa & Riyanto, 2022). This is done to support the framework that access to water will support increased productivity, income and business opportunities (James et al., 2002; Sefiani & Bown, 2013). (James et al., 2002; Mendiguren, 2004; Moriarty et al., 2004; Noel et al., 2010; Polak et al., 2003). The percentage of small and micro industries in this study is measured by Equation (2).

$$Y_{it}^{2} = \frac{jumlah\ industri\ kecil\ gerabah/keramik/batu/makanan/minuman_{\ it}}{Jumlah\ Rumah\ Tangga_{it}} \quad (2)$$

With Y_{it}^{2} is the calculation for the dependent variable (Y^{2}) is the percentage of small and micro industries in village i in the year t period, which is calculated from the number of small-scale pottery/ceramic/stone/food and beverage industries in village i in the year t period divided by the number of households in village i in the year t period.

In addition to the construction of boreholes, the prevalence of diarrhea can be influenced by other factors such as adequate sanitation and hygiene facilities (Komarulzaman et al., 2017; Kustanto, 2015; Patunru, 2015; Semba et al., 2011; Sukartini & Saleh, 2016; Susanti et al., 2016), pollution and awareness of environmental hygiene (Aluoch et al., 2008; Mamady, 2016; Quick et al., 1999; Shaheed et al., 2014; Sodha et al., 2011; UNICEF & WHO, 2015; Vollaard et al., 2004; Wright et al., 2004), and health personnel and infrastructure (Azage et al., 2016; Chowdhury et al., 2015; Sarker et al., 2016).Adequate sanitation facilities are represented by the presence of private/communal latrines and temporary waste disposal sites. Pollution and hygiene awareness are measured by the presence of slums, dumping sites, and water pollution. Health workers and infrastructure are represented by the number of health workers living in the village and ease of access to health facilities such as hospitals, puskesmas, posyandu, and clinics.

For the next hypothesis, it is possible that the increase in the percentage of small and micro industries in the village is influenced by other factors such as economics and social relations. (Ahmed & Rashid, 2012; Islam & Hossain, 2018; Polak et al., 2003; Wirawan & Gultom, 2021), level of remoteness and transportation access (Cesar et al., 2018; Nisa & Riyanto, 2022; Shofawati, 2019; Zipper et al., 2017) as well as access to education and information (Mambula, 2002; Nisa & Riyanto, 2022).. Economy and social relations are proxied by the main source of income of most residents, the presence of markets, access to financial institutions and the mutual cooperation habits of residents in the village. Remoteness and transportation access are proxied by the topography of the village area, the presence of the village on the island of Java or other islands, the village is located in a coastal area and the type of transportation facilities and infrastructure between villages. Access to education and information is proxied by the presence of primary schools, junior high schools and senior high schools in the village as well as the presence of television and cellular telephone signals. The use of these control variables is expected to capture the influence of other specific factors that only exist in the village.

After obtaining the treatment and control groups, the impact of the borehole development program on the prevalence of diarrheal diseases and the percentage of small and micro industries can be estimated using Equation (3).

$$Y_{it}^{k\,1,2} = \beta_0^{k\,1,2} + \beta_1^{k\,1,2}\, year\_borehole_t + \beta_2^{k\,1,2}\, borehole_i + \beta_3^{k\,1,2}\, borehole_i \times year\_borehole_t + \beta_4^{k\,1,2}\, control_{it} + \gamma_i + \delta_t + u_{it} \qquad (3.3)$$

With $Y_{it}^{k\,1}$ is the prevalence of diarrhea in village *i* in year t ; $year\_borehole_t$ is a *dummy for the* implementation time of the borehole program, where 1 means the year the borehole was built and the years after, and 0 if it is not yet operational/not implemented; $borehole_i$ is a dummy for the treatment group, i.e. villages that received the borehole program, where 1 means borehole villages and 0 otherwise; $control$ is the control variable in this study that includes several dummies representing the infrastructure and environmental conditions in the village at a certain period: dummy *(slump)* for slums, dummy (*sanitation)* for type of defecation site, *dummy (selftrash)* for waste management, dummy (*garbage)* for the presence of TPS, dummy (*contamination)* for water pollution, dummy (*medic)* for the presence of health workers, and *dummy (healthcare)* for access to health facilities. Each *dummy takes* the value of 1 if the condition exists or is present in the village in the year in question and 0 if it does not exist or is not present; γ_i is *individual fixed effects*; δ_t is *year effects*, and u_{it} is the *error term* for each Diarrhea disease prevalence in village i in year t. The use of *year effects* is to capture the average outcome in each village in each year, thus ensuring the main explanatory coefficient (β_3^{k1}) can measure the variation of the impact of the Bore Well development program in each year. Based on previous literature studies and the description above, the relationship that can be assumed is that the construction of boreholes has an impact on the prevalence of diarrheal diseases.

Still in Equation (3) with $Y_{it}^{k\,2}$ is the percentage of small and micro industries whose production activities mostly use water, namely pottery/ceramic/stone/food and beverage industries in village *i* in year t*;* $year\_borehole_t$ is a *dummy for the* time of implementation of the borehole program where 1 means the year when the borehole was built and the years after, and 0 if it has not been operated/not implemented; $borehole_i$ is a dummy for the treatment group, i.e. villages that received the borehole program, where 1 means borehole villages and 0 otherwise; for the variable $control$ The control variables in this study include several *dummies* that reflect the infrastructure and socioeconomic conditions in the village at a certain period: *dummy (financial)* for the availability of financial institutions such as banks or savings and loan cooperatives, dummy (*market)* for permanent or semi-permanent market access, dummy (*work)* for the main source of income from the agrarian sector, *dummy (communalwork) for the* habit of gotong royong, dummy (*topography)* for terrain topography, dummy *(transportation)* for land traffic access, dummy *(*island*)* for geographical location in Java, dummy *(coast)* for villages directly adjacent to the sea, *dummy (primaryschool)* for primary school availability, dummy *(juniorhighschool)* for junior *high* school, dummy *(highschool)* for senior high school, *dummy (TVsignal)* for local television signal, and dummy *(HPsignal)* for cell phone signal. Each *dummy takes* the value of 1 if the condition is present or yes in the village in the respective year and 0 if it is absent or not; γ_i is *individual fixed effects*; δ_t is *year effects*, and u_{it} is the error term for each percentage of small and micro industries whose production activities mostly use water, namely the pottery/ceramic/stone/food and beverage industry to the number of households in village *i* in the period of year *t*. The use of *year effects* is to capture the average outcome in each village in each year, so as to ensure that the main explanatory coefficient (β_3^{k2}) can measure the variation of the impact of the Bore Well development program in each year. Based on previous literature studies and the description above, the relationship that can be assumed is that the construction of boreholes has an impact on the percentage of small and micro industries.

To obtain accurate Difference-in-Differences (DiD) estimates in equations (2) and (4), it is important to observe the parallel-trend assumption. This assumption requires that the random disturbance (error term) is uncorrelated with other variables in the equation, indicating that unobserved factors affecting the program do not change over time in either the treatment or control group. However, it is difficult to fulfill this assumption in the field, especially if the control group consists of untreated villages, which can have heterogeneous characteristics that violate the parallel-trend assumption (Khandker et al., 2010; Gertler et al., 2016). To ensure the validity of this assumption, the Placebo Test method can be applied by using pre-treatment observations, as has been done in previous research by Wirawan & Gultom (2021). This method allows researchers to evaluate whether the trend before the intervention is similar between the group that actually receives the treatment and the control group that should not receive the treatment. can be done using Equation (4).

$$Y_{it}^{k\,1,2} = \beta_0^{k\,1,2} + \beta_1^{k\,1,2}\ timerescale_t + \beta_2^{k\,1,2}\ timerescale_t \times borehole_i + \gamma_i + \delta_t + u_{it} \quad (4)$$

With Y_{it} is the dependent variable consisting of two (*k*), namely *k1* is the prevalence of diarrhea and *k2* is the percentage of small and micro industries that most of their production activities use water, namely the pottery/ceramic/stone/food/beverage industry in village i in the period of year t. The variable $timerescale$ is a *dummy* for the year of escalation, with 0 as the initial year of the borehole program (2019), and negative (-1, -2, -3) and positive (1, 2, 3) values for the years before and after. $borehole$ is a dummy for villages that received borehole wells, with 1 indicating villages that received the program, and 0 for those that did not. The coefficient $\beta_2^{k\,1,2}$ captures the difference in pre-treatment trends between the treatment and control groups. The null hypothesis for $\beta_2^{k\,1,2}$ is that there is no trend difference between these two groups before treatment.

4. Data

This study used data from the Central Bureau of Statistics (BPS) and the Ministry of Energy and Mineral Resources (ESDM). Data on villages that received benefits from the Bore Well program were obtained from the Ministry of Energy and Mineral Resources, while village characteristics and other variables were obtained from BPS. PODES data for 2014, 2018, 2019, 2020 and 2021 were used in this study. Data on the construction of boreholes prior to 2014 was not included due to data availability and the lag period was too far. According to KESDM, the borehole construction program was implemented from 2005 to 2020, with a total of 3,475 units spread across 1,864 sub-districts, 396 districts, and 35 provinces. The 2014 and 2018 PODES data was used for the situation before the program implementation, while the 2019-2021 data was used for after implementation. Meanwhile, boreholes built in 2019 with a total of 573 units, spread across 552 villages, 465 sub-districts, 220 districts and 35 provinces. The impact estimation will be based on the 2019 borehole program data due to the availability of adequate data. This study focuses on villages that are administratively categorized as village areas and the majority have not used piped water as the main source of water, so access to clean water is still relatively minimal. Control villages were selected from the same kecamatan as the treatment villages to minimize differences in geographical and policy characteristics. The sample villages in this study include 745 treatment villages and 3,805 control villages, spread across Indonesia, for a total of 4,550 villages as samples.

Table 1. Characteristics of the Control and Treatment Groups

Characteristics	Control Group		Treatment Group		T test (p-value)
	2014	2021	2014	2021	
Villages where the majority of neighborhoods throw garbage in the trash	5.37%	11.41%	4.34%	12.22%	0.5789
Villages that have temporary waste collection sites (TPS)	4.03%	19.46%	6.70%	17.21%	0.2183
Villages with water pollution	13.42%	10.07%	12.22%	11.96%	0.6845
Villages traversed by SUTET / SUTT / SUTTAS	10.74%	17.45%	9.46%	16.69%	0.63
Villages that have village street lighting	79.19%	92.62%	82.13%	92.12%	0.398
Villages traversed by the river	81.21%	83.89%	87.91%	88.44%	0.9865
Villages with riverbank settlements	24.16%	14.09%	26.41%	14.72%	0.5674
Villages with slums	2.68%	5.37%	3.15%	3.42%	0.762
Household Sanitation with Latrines	83.89%	99.33%	83.57%	98.95%	0.923
Households using LPG/natural gas	65.10%	91.28%	63.07%	91.85%	0.6392
Households using kerosene fuel	0.00%	0.00%	0.66%	0.00%	0.3217
Household uses firewood/charcoal/coal fuel	34.90%	8.72%	36.27%	8.15%	0.75
Access to the village via land	95.30%	97.32%	97.77%	98.42%	0.0863
Access to the village via water	0.67%	0.00%	0.53%	0.00%	0.8263
Access to the village via land and water	4.03%	2.68%	1.71%	1.58%	0.0704
Village with the widest road that has been paved/concrete	74.50%	91.95%	74.24%	91.46%	0.9487
Number of observations	761	761	149	149	

Source: PODES processed, 2024

In general, Table 1 shows that the environmental characteristics between the treatment and control groups were similar, as shown by the *T-test* results with *p-values* that were not significantly different. Most households in both groups of villages have difficulty accessing clean water, with the majority not yet using PDAM as their main source. The lack of water, trash and sanitation infrastructure indicates a clean water crisis, confirming the relevance of the borehole program. Poor conditions such as lack of TPS, high water pollution, slums, and low awareness regarding hygiene indicate the urgent need for intervention. Meanwhile, there have been improvements in street lighting, transportation access, and the use of environmentally friendly fuels such as LPG and gas, reflecting progress in equitable distribution of more sustainable fuel conversions.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. dev.	Min	Max
prev	4550	0.0000839	0.001196	0	0.0482292
smallindus~y	4550	0.0124248	0.023279	0	0.4084919
borehole	4550	0.1637363	0.370077	0	1
borehole_t~e	4550	0.0982418	0.297674	0	1
slump	4550	0.0450549	0.207447	0	1
sanitation	4550	0.8362637	0.370076	0	1
selftrash	4550	0.0450549	0.045054	0	1
garbage	4550	0.0626374	0.242336	0	1
contaminat~n	4550	0.1241758	0.329818	0	1
medic	4550	0.9505495	0.216830	0	1
healtcare	4550	0.9417582	0.234225	0	1
financial	4550	0.4505495	0.497603	0	1
market	4550	0.2714286	0.444745	0	1
work	4550	0.9384615	0.240341	0	1
communalwork	4550	0.9901099	0.098966	0	1
topography	4550	0.767033	0.422767	0	1
transporta~n	4550	0.9736264	0.160261	0	1
island	4550	0.7285714	0.444745	0	1
primarysch~l	4550	0.9791209	0.142995	0	1
juniorhigh~l	4550	0.5769231	0.494101	0	1
highschool	4550	0.3263736	0.468937	0	1
TVsignal	4550	0.9956044	0.066160	0	1
HPsignal	4550	0.9846154	0.123090	0	1
coast	4550	0.0692308	0.253874	0	1

Source: KESDM and PODES processed, 2024

Descriptive statistics in Table 2 show the development of adequate sanitation and health infrastructure in the villages sampled, with 84 percent of villages having private or public latrines, and 94 percent of villages having access to rural health facilities. The majority of villagers work as farmers, accounting for 94 percent of the study sample, while social cooperation habits are very high with an average of 99 percent. Public infrastructure shows progress with 97 percent of villages having access to land transportation. Education infrastructure which includes 98 percent of villages have primary schools, 57 percent have junior secondary schools and 32 percent have senior secondary schools. This is coupled with access to information which includes television signals in 98 villages and cellular phone signals in 99 percent of sample villages.

Nonetheless, hygiene infrastructure is still limited with only 6 percent of villages having waste disposal sites (TPS), and the water pollution rate is still quite high at 12 percent, reflecting the low awareness of environmental hygiene in rural areas. Village economic infrastructure is also underdeveloped, with only 27 percent of villages having markets, limiting opportunities for small industries to sell their products. Geographically, most of the sample villages are located on the island of Java at 72 percent, with the majority being plains at 76 percent and the rest being on slopes or mountains. Only 7 percent of villages have coastal areas.

5. Results

DiD calculations are performed on equations that have met the assumption of parallel trends. DiD estimation calculations were carried out on two dependent variables, namely diarrhea prevalence (prev) and the percentage of *small* industries (food, beverages, pottery / stone processing) to the number of households (*smallindustry*). Figure 1 shows the results that the trend has the same average pattern of treatment and control samples, on both variables when before the policy so that the parallel trend assumption is met.

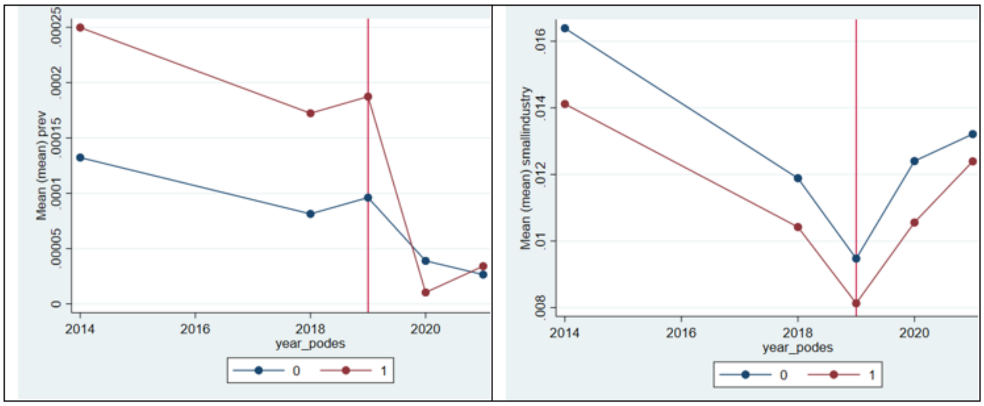

Figure 1. Visual Pre-Treatment Test Results
Source: KESDM and PODES processed, 2024

Hypothesis testing is done through panel data regression. Panel data regression was conducted using Equation (3), with the regression results shown in Table 3 In column (1), only the basic model was used, i.e. regression with *borehole, year_borehole,* and *year_borehole × borehole*. In column (2), control variables are added that describe sanitation facilities and hygiene facilities. In column (3), regression is performed by adding the variables of pollution and environmental hygiene awareness. Then in column (4), all control variables are analyzed by adding the availability of health personnel and infrastructure. Table 3 shows that the coefficient of the interaction variable *year_borehole × borehole* (β_3^{k1}), is not statistically significant in all columns: column (1) = -0.000082, column (2) = -0.000082, column (3) = -0.000085, and column (4) = -0.0000824. The best result was obtained using all control variables, R-Squared = 0.0043. This suggests that the borehole program has no significant impact on diarrhea prevalence or health, consistent with the results of Adams (2015) and Devoto et al. (2012), but in contrast to other studies that show a positive correlation between clean water access and diarrhea prevalence (Esrey et al., 1988; Tonglet et al., 1992; Wang et al., 1989).

Table 3. Results of DiD Estimation of Borehole Wells against Diarrhea Prevalence

	Basic Model	The Model with	The Model with	The Model with
	(1)	Control Variable (2)	Control Variable (3)	Control Variable (4)
Independent Variable:				
year_borehole x borehole	-0.000082	-0.000082	-0.0000816	-0.0000817
	(0.0001359)	(0.000136)	(0.0001359)	(0.000136)
year_borehole	-0.0000518	-0.0000518	-0.0000518	-0.0000518
	(0.0000421)	(0.0000421)	(0.0000421)	(0.0000421)
borehole	0.0001053	0.0001096	0.0001128	0.0001168
	(0.0001275)	(0.0001263)	(0.0001259)	(0.000128)
Observations	4,550	4,550	4,550	4,550
R-squared	0.0012	0.0022	0.0028	0.0043
Number of Villages	910	910	910	910

Notes: Confidence level 99% (***), 95% (**), 90% (*). Robust standard errors in brackets.

Model with Control Variable in column (2): sanitation, garbage. Control Variable in column (3): sanitation, garbage, slump, selftrash, contamination. Control Variable in column (4): sanitation, garbage, slump, selftrash, contamination, medic, healthcare.

Source: KESDM and PODES processed, 2024

Hypothesis testing is done through panel data regression. Panel data regression was conducted using Equation (3), with the regression results shown in Table 4 In column (1), only the base model was used, i.e. regression with *borehole, year_borehole,* and *year_borehole × borehole* . In column (2), control variables are added that describe economic and social relations. In column (3), regression is performed by adding the variables of remoteness and transportation access. Then in column (4), all control variables are analyzed by adding access to education and information. Table 4 shows that the coefficient of the interaction variable *year_borehole × borehole* (β_3^{k2}), is not statistically significant in all columns: column (1) = 0.0005151, column (2) = 0.0005151, column (3) = 0.0005151, and column (4) = 0.0005151. The best result was obtained using all control variables, R-Squared = 0.0272. This indicates that the borehole program has no significant impact on the percentage of small and micro industries, consistent with the results of Davis et al. (2001), but in contrast to other studies that show a positive correlation between access to clean water and small and micro industries (Boelee & Laamrani, 2004; James et al., 2002; Jehangir et al., 1998; Mendiguren, 2004).

Table 4. Estimation Results of the DiD of Boreholes against the Percentage of Small Industries

	Basic Model (1)	The Model with Control Variable (2)	The Model with Control Variable (3)	The Model with Control Variable (4)
Independent Variable:				
year_borehole x borehole	0.0005151	0.0005151	0.0005151	0.0005151
	(0.0015702)	(0.00157)	(0.00157)	(0.00157)
year_borehole	-0.0024***	-0.002423***	-0.002424***	-0.002424***
	(0.000734)	(0.0007343)	(0.0007347)	(0.0007351)
borehole	-0.0018667	-0.00169	-0.0010053	-0.00746
	(0.0019533)	(0.00195)	(0.00193)	(0.001918)
Observations	4,550	4,550	4,550	4,550
R-squared	0.0031	0.0045	0.0181	0.0272
Number of Villages	910	910	910	910

Notes: Confidence level 99% (***), 95% (**), 90% (*). Robust standard errors in brackets.

Model with Control Variable in column (2): market, financial, work, communalwork. Control Variable in column (3): market, financial, work, communalwork, topography, island, coast, transportation. Control Variable in column (4): market, financial, work, communalwork, topography, island, coast, transportation, primaryschool, juniorhighschool, highschool, Tvsignal, Hpsignal.

Source: KESDM and PODES processed, 2024

Heterogeneity testing on both hypotheses was also carried out by dividing by sub-sample geographical characteristics, namely the policy of providing boreholes on the island of Java and outside the island of Java. The *year_borehole × borehole* values show that boreholes have no impact on the prevalence of diarrhea and the percentage of small industries both on Java Island and outside Java Island, because the coefficient ($\beta_3^{k\ 1,2}$) is not statistically significantly different from zero.

Furthermore, testing the two hypotheses also conducted a heterogeneity test on the sub-sample based on the number of wells, namely provincial groups that have ≤5 (less than or equal to five) units, 6-20 (six to twenty) units and >20 (more than twenty) units built in 2019. With the same method and regression, the results in Table 6. *year_borehole × borehole* values show that boreholes have no impact on the prevalence of diarrhea and the percentage of small industries in each provincial group.

Table 5. Analysis Results of Sub-Sample Based on Geographical Location

Dependent Variable:	Sub Sample Coefficient: Diarrhea Prevalence		Sub Sample Coefficient: Percentage of Small Industries	
	Java	Outside Java	Java	Outside Java
Basic Model:				
year_borehole x borehole	0.0000124	-0.0001633	0.000327	-0.0005186
	(0.0000841)	(0.0003571)	(0.0022597)	(0.0014346)
year_borehole	0.0000197	-0.000262*	-0.0036***	0.0009667
	(0.0000238)	(0.0001497)	(0.0009444)	(0.000761)
borehole	0.0000167	0.0001819	-0.0013132	-0.0006063
	(0.0000333)	(0.0003602)	(0.0028102)	(0.0016121)
R-squared	0.0003	0.0065	0.0047	0.0018
With Control Variable:				
year_borehole x borehole	0.0000163	-0.0001679	0.0002454	-0.0004161
	(0.0000856)	(0.0003223)	(0.0022565)	(0.0014554)
R-squared	0.0029	0.0258	0.0237	0.0631
Observations	3,315	1,235	3,315	1,235
Number of Villages	663	247	663	247

Notes: Confidence level 99% (***), 95% (**), 90% (*). Robust standard errors in brackets.

Model with Control Variable for Diarrhea prevalence: sanitation, garbage, slump, selftrash, contamination, medic, healthcare. Model with Control Variables for Percentage of Small Industries: market, financial, work, communal work, topography, island, coast, transportation, primaryschool, juniorhighschool, highschool, Tvsignal, Hpsignal.

Source: KESDM and PODES processed, 2024

Table 6. Results of Sub-Sample Analysis Based on Number of Wells by Province

Dependent Variable:	Sub Sample Coefficient					
	Diarrhea Prevalence			Percentage of Small Industries		
	≤5 Units	6-20 Units	>20 Units	≤5 Units	6-20 Units	>20 Units
Basic Model:						
year_borehole x borehole	-0.00011	-0.00013	0.000053	0.000056	0.000428	- 0.00037
	(0.0004)	(0.00008)	(0.0001)	(0.0017)	(0.0021)	(0.0029)
year_borehole	0.00033*	0.000047	0.00001	0.00072	-0.00037	-0.004***
	(0.00018)	(0.00006)	(0.00002)	(0.00088)	(0.00006)	(0.0012)
borehole	0.000124	0.0000642	0.0000327	-0.00082	-0.00193	-0.0003
	(0.00041)	(0.0001)	(0.00004)	(0.0018)	(0.0017)	(0.0037)
R-squared	0.0075	0.0008	0.0015	0.0013	0.0022	0.0060
With Control Variable:						
year_borehole x borehole	-0.00011	-0.000138	0.000053	0.00005	0.00042	-0.0004
	(0.00041)	(0.00008)	(0.00011)	(0.00171)	(0.0021)	(0.0029)
R-squared	0.0334	0.0022	0.0038	0.048	0.1176	0.028
Observations	1,025	1,065	2,460	1,025	1,065	2,460

Table 6. (Extension)

Dependent Variable:	Sub Sample Coefficient					
	Diarrhea Prevalence			Percentage of Small Industries		
	≤5 Units	6-20 Units	>20 Units	≤5 Units	6-20 Units	>20 Units
Number of Villages	205	213	492	205	213	492

Notes: Confidence level 99% (***), 95% (**), 90% (*). Robust standard errors in brackets.

Model with Control Variable for Diarrhea prevalence: sanitation, garbage, slump, selftrash, contamination, medic, healthcare. Model with Control Variables for Percentage of Small Industries: market, financial, work, communal work, topography, island, coast, transportation, primaryschool, juniorhighschool, highschool, Tvsignal, Hpsignal.

Source: KESDM and PODES processed, 2024

6. Analysis and Discussion

The DID estimation results show that the policy of providing access to clean water through boreholes has no impact on diarrhea prevalence rates and this contradicts other studies that show that access to clean water has an influence on diarrhea outbreaks and other health risks (Aluoch et al., 2008; Cairncross & Cuff, 1987; Esrey et al., 1988; Klees et al., 2016; Kustanto, 2015; Quick et al., 1999; Rosen & Vincent, 1999; Skoufias, 1998; Sorenson et al., 2011; Tonglet et al., 1992; Wang et al., 1989). Based on 2019 borehole construction data, an average of 1 village has only 1.03 borehole units. With the specifications owned, it is estimated that each borehole can serve the clean water needs of up to 2,160 people per unit (KESDM, 2019b, 2019a). With this data, the details of borehole coverage data per year are shown in Table 7.

Table 7. Percentage of Average Coverage of Boreholes in 2019

Year	2019	2020	2021
Average Population of Sumur Bor Village	4517	4533	4598
Coverage per unit	2160	2160	2160
Percentage Coverage	48%	48%	47%

Source: KESDM and PODES processed, 2024

Based on Table 7, boreholes are only able to meet the needs of less than half of the villagers in villages where boreholes were constructed. Specific data on access, distance and location of boreholes in each village is not available. It is suspected that clean water coverage from boreholes may not be adequate for all villagers. The most effective borehole locations are in areas with good groundwater aquifers, such as mountainous areas with permeable rock formations, geological basins with large sedimentary deposits, or lowlands with sand, gravel and limestone deposits (Todd, 1980). As a result, boreholes may be located far from residential areas, so people are less interested in using borehole water and prefer conventional water sources (rainfed or surface) that are more susceptible to contamination.

In addition, this result may be due to the lack of public awareness in treating water from boreholes so that it is not effective in reducing the risk of diarrhea due to *E. coli* as described in the studies of Adams (2015), Clasen et al. (2007), Fiebelkorn et al. (2012), Sodha et al. (2011), and Wright et al. (2004). Added to this is the possibility that most groundwater in Indonesia contains *E. Coli* bacteria, especially in unprotected wells (Dayanti et al., 2018; Genter et al., 2022; Jannah & Putri, 2021). Furthermore, the provision of clean water through boreholes does not have a significant effect on the percentage of small and micro industries, in contrast to other studies that show an effect of clean water access on the number of small and micro industries (Boelee & Laamrani, 2004; James et al., 2002; Jehangir et al., 1998; Mendiguren, 2004). Location factors that may be far from settlements and the designation of boreholes with existing specifications may be more likely to be used for daily activities than for small and micro industries, as described in the study by Davis et al. (2001).

7. Conclusions and Recommendations

The estimation results do not show a significant impact of the borehole program on the prevalence of diarrhea and the number of small and micro industries, so the government needs to evaluate and supervise so that this program has more impact on the community, especially in encouraging improvements in health quality through reducing the prevalence of diarrhea, and increasing economic activity through increasing the number of small and micro industries. If the government wants to optimize the benefits of boreholes, especially to reduce the prevalence of diarrhea and increase the number of small and micro industries, it may need to consider the number of boreholes per village, bring or connect pipeline access from the borehole location to households and industrial centers, and conduct periodic testing of borehole water quality.

The author acknowledges that this research is not perfect, and still needs further research, considering that this research only focuses on the borehole program in Indonesia in 2019 and looks at the impact until 2021 and in villages within the same sub-district. This leads to results that only describe certain areas and do not capture medium and long-term impacts. Adding other control variables that have not been included in this study but could potentially affect the results, such as COVID-19 affected villages that have not been included in this study due to data limitations, or other information related to the specific location and access to boreholes in each village could be an important element to add validation to the results. In addition, this study used PODES data which was analyzed at the community/village level, so changes in people's behavior in using water for health and small industries sourced from boreholes at the individual level were not captured.

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