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Impact of investment capital on the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam

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Abstract: *Access to clean water in the Northern Midlands and Mountains region of Vietnam is facing many difficulties due to complex terrain and limited infrastructure, leading to a lack of clean water and poor service quality. This is an urgent issue that needs to be addressed to improve people's health and lives. Therefore, this study aims to assess the impact of domestic public and private investment and foreign direct investment (FDI) on the current situation of clean water supply in this region, thereby contributing to policy improvement and improving the efficiency of investment capital use. The study used a mixed-methods approach, combining in-depth interviews with officials and local people with quantitative analysis of secondary data collected during 2020-2024 from 14 provinces in the region. The results of the study show that public investment capital has a significant negative impact on the level of access to clean water while FDI capital has a positive impact. The study did not find any impact of private domestic investment capital on the use of clean water. In addition, there is a positive impact of the control variable GRDP per capita on access to clean water. The interview results also show a clear difference in access to clean water among population groups, especially in highland and remote areas, along with the gap between the assessment of local authorities and the reality of people's lives. From there, practical implications are proposed as reviewing the allocation mechanism and efficiency of public investment capital, and promoting the public-private partnership model to improve efficiency. The government should prioritize attracting FDI into the clean water supply sector, creating favorable conditions in terms of policies and procedures. It is necessary to develop zoning and localization policies suitable to the terrain characteristics, developing flexible solutions such as household filtration systems, rainwater tanks, and using renewable energy in disadvantaged areas. In addition, increasing transparency, feedback, and monitoring from the community are necessary to ensure efficiency and equity in the provision of clean water services.*

Keywords: Clean water supply, ethnic minority, investment capital, Northern Midland and Mountainous Region, sustainable water.

1. INTRODUCTION

Providing clean water is one of the fundamental factors for achieving sustainable development, which is closely linked to public health, social equality, climate change adaptation and labor productivity. According to the United Nations, ensuring access to clean water and sanitation for all is Sustainable Development Goal 6 (SDG 6) – a goal that is directly linked to at least 10 of the other 17 sustainable development goals, including health, education, gender, energy and social equity. Accessing to clean water significantly reduces the burden of disease and health care costs, thereby improving labor productivity and quality of life, contributing to poverty reduction. According to the UN, more than 800,000 people die every year from diseases related to unsafe water and poor sanitation, while access to clean water is one of the most effective health interventions (UN, 2022). At the same time, water is also a decisive factor for food production, energy production, and ecosystem protection, which are the foundation for sustainable prosperity. Climate change increases water resource instability, such as droughts and floods. Effective water management is a key strategy for adapting to climate change. Lack of safe water increases conflict, migration, and inequality which especially affects women and children (UNESCO World Water Assessment Programme, 2024).

In Vietnam, ensuring clean water supply and rural environmental sanitation is one of the key tasks outlined in the National Strategy on Rural Clean Water Supply to 2030, with a vision to 2045. Although Vietnam has made progress in providing clean water to rural areas according to the national strategy, only about 51% of rural households use water sources that meet QCVN 02:2009/BYT quality standards (MOH, 2009), and the Northern mountainous region has a much lower rate than the national average. This is explained by the fact that the Northern Midland and Mountainous region of Vietnam is a complex terrain area, facing many difficulties in ensuring clean water supply for residential communities, especially in ethnic minority areas, high and scattered mountain slopes. A report by the Ministry of Agriculture and Rural Development (MARD) shows that many localities in this region have a

significantly lower rate of households using clean water than the national average, especially in provinces such as Ha Giang, Cao Bang, Dien Bien, and Son La. Ensuring the growth of clean water supply here is a significant challenge in terms of technology, policy and investment resources (MARD, 2021).

Although there are many studies focusing on the performance of rural water supply systems in Vietnam, most of them stop at describing the current situation or general assessment without clearly quantifying each type of investment. For example, the study in Ha Nam province used the Fuzzy-AHP method to identify factors affecting the investment decisions of the private sector, including tax incentives, credit support, risk sharing mechanisms and water prices, but still stopped at building an investment attractiveness index without assessing the actual impact on access to clean water (Nguyen et al., 2023). In addition, many international studies mentioned the PforR model and investment based on results, but still focused on the plains or urban areas. Quantitative studies on the efficiency of investment capital in mountainous areas, especially the Northern Midland and Mountainous region, are still very limited. Therefore, conducting research to measure the effectiveness of each type of investment on the quality and sustainability of clean water supply systems in this region would fill an the research gap in both theoretical and policy perspectives. This study was conducted with the main objective of assessing the impact of investment capital through public investment capital, private investment capital and foreign direct investment capital on the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam. The structure of the research paper includes 5 main parts: introduction, conceptual framework and hypothesis development, research methodology, results and discussion, and implications and conclusion

2. CONCEPTUAL FRAMEWORK AND HYPOTHESIS DEVELOPMENT

2.1 Investment capital and its types

Investment capital is the total monetary value of resources mobilized to carry out investment activities to create fixed assets or upgrade, expand production and business scale, develop infrastructure, or improve production capacity (UNCTAD, 2023). According to Berry (1984), investment capital can include financial resources, tangible assets, technology, land use rights and other property rights. Based on the statistical indicators of the General Statistics Office of Vietnam (now National Statistics Office), in the context of international socio-economic development in general and the midland and mountainous region of the North in Vietnam in particular, investment capital is divided into three main groups including state investment capital (public), and private domestic investment capital & foreign direct investment (FDI), in which both of them can be known as non-state investment capital.

State or public investment capital is capital owned or directly managed by the State. According to Poterba (1995), this capital includes the state budget, preferential loans with government guarantees, development investment capital of state-owned enterprises and other public investments. The outstanding feature of state capital is that it is development-oriented, often prioritized for allocation to essential areas such as infrastructure, education, health, science - technology, national defense - security and development of disadvantaged areas. Ermasova & Mikesell (2024) emphasize that public investment not only contributes to macroeconomic regulation but also helps to achieve social equity goals, reduce regional disparities and promote inclusive growth. In addition to its direct investment function, state capital also plays a “leading” role in the market, contributing to attracting resources from the private sector through support policies, investment incentives and forms of public-private partnership (PPP). According to Wu & Lin (2022), PPP programs are increasingly becoming an important tool in attracting non-budgetary capital into public sectors, especially in disadvantaged areas.

Non-state investment capital includes capital from organizations, individuals and enterprises not in the state sector, including domestic enterprises and enterprises with foreign investment capital. Doroshenko et al. (2013) believe that this is a group of capital with a clear market character, in which investment decisions are based on cost-benefit analysis, risk level and profit prospects. This source of capital is often flexible, responsive and adapts well to socio-economic fluctuations. Serven & Solimano (1992) believe that the dynamism of the private sector can help improve investment efficiency and reduce the burden on the state budget in the process of economic development. In Vietnam, the private sector plays an increasingly large role in the structure of social investment capital. According to Hakkala & Kokko (2007), and recently An (2024), policies to promote private enterprises, reform the investment environment and reduce institutional barriers have created conditions for this sector to develop strongly, contributing to technological innovation, creating jobs and promoting economic growth.

In which, according to the definition of the Organization for Economic Cooperation and Development (OECD, 2008), FDI is an investment by an individual or organization residing in one country into an enterprise headquartered in another country, with the aim of establishing a long-term interest relationship and significant control over that enterprise. In Vietnam, the Investment Law (amended in 2020) defines FDI as a form of investment made by foreign investors through the establishment of economic organizations, capital contribution, purchase of shares, capital contributions or investment under contracts. FDI is considered an important resource to help transfer technology, management skills, expand markets and improve the competitiveness of the economy (Mai et al., 2023; Madani et al., 2024). In the midland and mountainous regions of the North, despite limited geographical conditions and infrastructure, FDI still has development potential if there are

appropriate incentive policies, improved investment environment and enhanced regional connectivity.

2.2 Current status of clean water supply in the Northern Midland and Mountainous region of Vietnam

In recent years, the Vietnamese government has made great efforts to expand the coverage of the clean water supply system nationwide. According to the latest statistics, about 74.2% of rural households have access to clean water that meets standards, of which 55.1% use the centralized water supply system and 19.1% exploit on-site hygienic water sources such as drilled wells and household filters (Vietnam News, 2024). However, the rate of access to clean water in the Northern Midland and Mountainous region is still significantly lower due to complex terrain, scattered population and underdeveloped infrastructure. However, the national target by 2025 still requires that at least 65% of the rural population and almost all of the urban population have access to clean water, with water loss reduced to below 10% (according to Decision No. 1719/QD-TTg).

Table 1: Percentage of population using clean water sources by regions from 2020 to 2024 in Vietnam (%)

Regions	2020	2021	2022	2023	2024
Red River Delta	99,8	99,9	99,8	99,9	99,9
Northern Midland and Mountainous	86,4	89,0	92,1	93,5	93,4
North Central and South Central Coast	96,0	97,7	97,8	98,4	98,3
Central Highlands	96,7	97,4	97,9	97,3	98,3
Southeast	99,9	99,9	99,8	99,8	99,8
Mekong River Delta	97,5	98,5	98,5	99,1	99,0
The whole nation	96,5	97,5	98,0	98,4	98,5

Source: National Statistics Office, 2025

During the period from 2020 to 2024, the proportion of the population using clean water sources in the Northern Midland and Mountainous region has improved significantly, increasing from 86.4% to 93.4%. However, compared to the national average of 98.5% in 2024, this region is still about 5 percentage points lower, and continues to be the region with the lowest access rate in the country. Meanwhile, developed urban areas such as the Red River Delta, Southeast or Mekong River Delta have maintained very high rates, stable at over 99% for many consecutive years. Even semi-mountainous regions such as the Central Highlands or the North Central and South Central Coast regions will achieve access rates of over 98% by 2024. This disparity reflects the unique challenges of the northern mountainous region including rugged terrain, dispersed population, and inadequate water supply infrastructure and poses an urgent need for increased investment, technical support, and public awareness raising to ensure sustainable development and equitable access to clean water and sanitation services nationwide.

Table 2: Percentage of population using clean water sources in Northern Midland and Mountainous region from 2020 to 2024 in Vietnam (%)

Provinces	2020	2021	2022	2023	2024
Ha Giang	58,8	67,9	78,3	80,5	78,2
Cao Bang	65,1	72,2	77,3	74,3	66,0
Bac Kan	90,5	89,0	97,6	92,2	90,0
Tuyen Quang	85,3	93,6	90,4	92,4	92,3
Lao Cai	93,8	90,0	94,7	97,0	99,3
Yen Bai	77,3	86,8	80,8	90,0	95,3
Thai Nguyen	97,8	98,5	98,0	99,1	99,6
Lang Sơn	97,6	98,7	93,5	95,9	97,0
Bac Giang	99,3	99,8	99,9	100,0	99,9
Phu Tho	97,8	98,4	98,6	96,7	100,0
Dien Bien	79,5	73,0	85,2	93,1	88,0
Lai Chau	88,3	83,6	94,4	91,9	94,1
Son La	72,0	78,0	87,0	90,8	85,8
Hoa Binh	92,4	95,7	98,1	95,5	98,2

Source: National Statistics Office, 2025

Although the statistics look quite positive, the quality of clean water in the Northern Midland and Mountains is still inadequate. A report from UNICEF shows that only about 51% of households have access to water that meets the standards of QCVN 01:2009/BYT of the Ministry of Health. Worryingly, about 44% of drinking water samples in rural areas contain Ecoli bacteria, reflecting widespread microbiological pollution due to substandard treatment systems or water sources affected by farming, livestock farming and domestic waste (UNICEF, 2021). In mountainous provinces such as Ha Giang, Cao Bang, Son La,… people still rely heavily on untreated water from streams and lakes, posing high risks to public health, especially during the dry season.

Accordingly, the sustainability of clean water supply systems is one of the major challenges in the Northern Midlands and Mountains. According to the World Bank

(2020), up to 30% of rural water supply works nationwide are degraded or stopped working after only 3-5 years of use. Common causes are poor construction quality, lack of maintenance budget and lax management. However, some sustainable water supply models have recorded clear effectiveness, typically the Results-Based Financing program funded by the World Bank in the Red River Delta, with more than 95% of the systems maintaining good operation after many years. In the Northern region, many communities have met the "sustainable clean water supply" standard by ensuring both technical, financial and social management (World Bank, 2020).

The Northern Midland and Mountainous areas face many unique challenges in developing clean water supply systems. The rugged terrain, dispersed population, and harsh climate conditions make it difficult to build a centralized water supply system. In addition, prolonged water shortages during the dry season, combined with floods and landslides during the rainy season, have damaged many works or rendered them unusable. The lack of a water storage and regulation system is also the reason why this area is susceptible to water supply interruptions. To overcome this, localities have been surveying groundwater sources, investing in water treatment and storage facilities, and calling for investment from the private sector through the PPP model. A typical example is the investment project to build water treatment plants in Thai Nguyen and Hai Phong with funding from Climate Investor Two (CI2), to increase the capacity to provide clean water to the Northern region (CA Water, 2024).

It can be seen that, despite some positive results, the clean water supply system in the Northern Midland and Mountainous region still faces many limitations in terms of coverage, water quality and sustainability of the project. To improve the situation, it is necessary to have synchronous coordination between the central and local governments in investing in infrastructure, strengthening operational management, promoting socialization and applying sustainable water supply models suitable to the geographical and social characteristics of this region.

2.3 Investment capital and the current status of clean water supply

The development of clean water supply systems is the result of many constituent factors, in which investment capital plays a key role in expanding infrastructure, upgrading water treatment technology, ensuring sustainability and accessibility of services for people. Public investment theory (Musgrave, 1959) and endogenous growth theory (Romer, 1990; Barro, 1991) both emphasize the role of investment - both public and private - in promoting basic infrastructure development, thereby improving the quality of public services such as clean water supply.

In the context of Vietnam, especially in disadvantaged areas such as the Northern Midlands and Mountains, attracting and effectively using investment capital sources becomes urgent to address the shortage of clean water, low quality of works and limited operation and maintenance capacity. Research by Vu et al. (2020) shows a positive relationship between the level of public investment in the clean water sector and the proportion of households with access to clean water in rural areas of Vietnam. Meanwhile, the Wu & Lin (2022) also emphasizes the increasing role of the private sector in developing clean water infrastructure through PPP models and independent investment. On that basis, this study analyzes three main factors related to investment capital, thereby building specific research hypotheses.

2.3.1 Public/State investment capital and the current status of clean water supply

Public investment plays a guiding role in the development of essential sectors such as water supply, especially in areas where the market is not attractive enough to attract the private sector. According to Musgrave (1959), public investment has the function of reallocating resources to reduce inequality and ensure public services for disadvantaged groups. For the Northern Midland and Mountainous region, where infrastructure is weak and investment costs are high, state budget capital is often used to build or upgrade clean water supply works, thereby improving coverage and service quality.

Several empirical studies have demonstrated the relationship between public investment capital and the current status of clean water supply in different contexts. A study by Greer (2020) evaluates the financing options available to public agencies to build and maintain water and wastewater infrastructure in the United States, an area that requires significant investment, with an estimated $1 trillion needed over the next 25 years to meet demand. Despite generally high drinking water quality, infrastructure systems are facing increasing stress and a significant funding gap that requires public investment to deliver clean water to the population. As Toan et al. (2023) analyzed the role of management models in ensuring the sustainability of rural water supply systems in Vietnam, in the context of clean water and sanitation being a global priority issue. By applying an ordered logit regression model, the results showed that the public investment management model and the private model have a significant impact on sustainability, in which the private management model contributes more effectively. Based on the above agurements, the following hypothesis is proposed:

H1: Public investment capital has an impact on the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam.

2.3.2. Private domestic investment capital the current status of clean water supply

While public investment is the guiding factor, domestic private investment plays an important role in improving the efficiency of water supply system exploitation and operation through market mechanisms. According to Komives et al. (2005), private participation often leads to improved service quality, reduced water loss and increased price transparency.

The World Bank (2020) also argues that the private sector can provide better water supply services if there are appropriate incentives, especially in small towns and urban areas where demand is growing rapidly.

A recent study by Nguyen et al. (2023) in Ha Nam province using the Fuzzy-AHP method pointed out the factors that promote private investment in rural water supply such as: preferential tax policies, credit, risk sharing mechanisms, price adjustment, input water sources and high community demand. In addition, another survey showed that people's satisfaction with the water supply system managed by the private sector is significantly higher than that of the community or local government model, and almost equivalent to that of the public-managed system (Anh et al., 2022). Based on the above agurements, the following hypothesis is proposed:

H2: Private domestic investment capital has an impact on the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam.

2.3.3. Foreign direct investment capital and the current status of clean water supply

Foreign direct investment in the water supply sector, is often associated with technology transfer, modern management, and international quality standards. Although FDI in water supply in Vietnam is still relatively limited, foreign-invested projects in large cities such as Hanoi, Da Nang, and Ho Chi Minh City have demonstrated outstanding efficiency in terms of capacity, water quality, and customer service (World Bank, 2014). For the northern mountainous region, attracting FDI faces many barriers such as low profits, high operating costs, and difficult terrain. However, in the context of sustainable development cooperation, some international organizations such as JICA, KOICA, or GIZ have funded rural water supply programs that combine modern techniques and local resource training (JICA, 2022). These forms of "socialized" FDI can open up new approaches for disadvantaged areas.

An empirical study by Totouom et al. (2024) analyzed the impact FDI on access to drinking water in 51 African countries over the period 2000–2020. The results showed that FDI is positively correlated with access to clean water, especially in rural areas. However, the relationship is inverted U-shaped, meaning that the improvement decreases as FDI increases above a certain threshold. The study also suggests the effective use of tax revenue from FDI enterprises to invest in basic service infrastructure and promote the attraction of additional FDI. However, although FDI has a positive impact in areas such as basic infrastructure, clean water, sanitation, and renewable energy, some adverse environmental consequences may occur for host countries (Aust et al., 2020). Irene (2022) also proved the positive impact of FDI on water quality and quantity in developing countries, especially the way in which they can affect access to clean water and sanitation of the poor and marginalized fractions of population. Based on the above agurements, the following hypothesis is proposed:

H3: Foreign direct investment capital has an impact on the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam.

3. METHODOLOGY

3.1 Measurement of constructs

Types of public investment (PUB), private domestic investment (PRD) and foreign direct investment (FDI) are calculated in millions of VND, while the current status of clean water supply (WAT) is measured by the percentage of population using clean water sources. In addition to the three main independent variables, the research model also adds a number of control variables to increase the accuracy in determining the relationship between investment and clean water supply. The control variables include GRDP per capita - GPC (million VND/person) and population density - POP (person/km²). The Multiple Linear Regression (MLR) model will be used to analyze the relationship between types of investment capital and clean water supply status, while controlling for the influence of other socio-economic factors.

Based on the research model, the equation is constructed as follows:

$$AFF = \beta_0 + \beta_1 * PUB_{it} + \beta_2 * PRD_{it} + \beta_3 * FDI_{it} + \beta_4 * GPC_{it} + \beta_5 * POP_{it} + e$$

Where i describes the provinces in the Northern Midland and Mountainous region and t describes the data period from 2020 to 2024. Accordingly, the study collected secondary data from 14 provinces in the 5-year period (2020-2024) with the corresponding number of 70 observations.

3.2 Sampling and data collection

This study was conducted using mixed research methods, firstly using qualitative research method to better understand: (1) the current situation of people's access to clean water in the area; (2) the support mechanism from the government for clean water issues; and (3) residents' wishes regarding clean water issues. The direct interview participants included 2 commune-level officials in charge of social security issues for the people, and representatives of 4 households living in the area. With the commune officials, the author will interview contents 1 and 2, while all 3 contents will be implemented with the households.

After that, the quantitative research method was used through collecting secondary data from the Provincial Statistical Yearbook and the General Statistics Office, thereby assessing the impact of investment capital types including public investment capital, private domestic investment capital, and foreign direct investment capital on the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam in the period of 2020-2024 (according to the most updated data of the Provincial Statistical Yearbook and the National Statistics Office). As of the data year, the Northern Midland and Mountainous region includes 14 provinces as Ha Giang, Cao Bang, Bac Kan, Tuyen Quang,

Lao Cai, Yen Bai, Thai Nguyen, Lang Sơn, Bac Giang, Phu Tho, Dien Bien, Lai Chau, Son La and Hoa Binh.

Accordingly, the study used SPSS 27 with statistical methods of exploratory analysis of descriptive data, data transformation (if necessary) and use multivariate regression method using Casewise diagnostics to predict outliers in the data set, thereby giving the best evaluation results for the research model and drawing conclusions for the research hypotheses.

4. RESULTS AND DISCUSSION

4.1 Qualitative research results

Content 1: On the current status of people's access to clean water:

Through interviews, people in the area use different water sources, commonly water from natural sources such as streams or from the district's water supply system. Most households also use water filters, especially those in the food service business. Some people rate the water as quite clean, disease-free, and the cost of water usage ranges from 100,000 to 300,000 VND/month depending on the conditions of each household.

However, there is a clear difference between population groups in terms of stable access. Some households reported that they have never experienced water shortages, while a household in a high terrain location said that they often do not have water for daily use despite having registered with the district. This household also reported that the water has a strong chlorine smell, causing discomfort to customers using food services at home. On the contrary, some other people use water directly from the stream, filter it briefly and think that the water is very clean, does not need further filtering and does not have any diseases related to the water source.

Content 2: Support mechanisms from local authorities

According to commune officials, the government has implemented a number of activities to support people in accessing clean water. Typically, it has installed water filtration systems in schools and organized communication and propaganda activities to raise awareness about the importance of clean water. Government representatives said that no cases of illness due to using dirty water have been recorded and highly appreciated the community's efforts in protecting water resources.

However, the results of interviews with people show that there is a gap between the government's assessment and the actual experience of the people. Some specific reflections on prolonged water shortages, strange-smelling water, and difficulties in accessing water due to terrain factors, show that the current support system is not really comprehensive and effective in more difficult areas.

Content 3: Residents' wishes regarding clean water issues

People expressed their wish to use a more stable and quality water source, especially in areas where the water supply system is not accessible due to complex terrain. Some people hope for stronger intervention from the government to improve water supply infrastructure and ensure water reaches every household. At the same time, ensuring water quality and avoiding the current chlorine smell is also a legitimate expectation from the people.

It can be seen that while commune officials have a relatively positive assessment of the clean water situation, in reality there are still certain difficulties that people are facing, especially in high terrain or remote areas. This is a point that shows the need for a more realistic assessment, as well as flexible policies that are suitable to local characteristics, instead of applying them uniformly.

4.2 Descriptive statistics result

Table 3 presents the descriptive statistics of the study sample of 70 observations. The WAT variable representing the proportion of the population with access to clean water has an average value of 89.54%, with a standard deviation of 10.03%. The lowest recorded value is 58.8%, while the highest reaches 100%. This shows that the level of access to clean water is generally high in the Northern Midlands and Mountains region, but the difference between provinces is significant.

Table 3: Sample descriptive statistics results (n=70)

Variables	Mean	S.D	Min	Max
WAT	89.54	10.03	58.80	100.00
PUB	4250961.49	1578688.75	1599127.00	9664400.00
PRD	8174681.47	5383239.10	1563840.00	24813800.00
FDI	2718398.20	5307086.15	143.00	20069700.00
GPC	53560.61	19520.25	28148.00	112590.30
POP	172.06	139.33	51.00	493.50

Source: Data analysis by SPSS 27

Regarding investment variables, public investment capital (PUB) has an average value of about 4.25 trillion VND, with a minimum of 1.6 trillion and a maximum of nearly 9.7 trillion VND. For domestic private investment capital (PRD), the average value is 8.17 trillion VND, significantly higher than public investment. However, the standard deviation is also very large (about 5.38 trillion VND), showing that only a few localities attract large private capital, while many other localities receive significantly lower investment levels. FDI capital also shows clear differentiation. The average level is about 2.72 trillion VND, but the minimum value is only 143

million VND, while the maximum value is up to more than 20 trillion VND. This reflects that FDI in the study area is uneven, and most localities still have difficulties in attracting foreign investment capital.

Control variables including GRDP per capita (GPC) and population density (POP) also have large differences between localities. The average GRDP is about 53.56 million VND/person, with the lowest being 28.1 million VND and the highest being over 112 million VND. This shows a significant difference in the level of economic development between provinces. Meanwhile, the average urban population density is 172 people/km², ranging from 51 to nearly 500 people/km², reflecting large differences in population pressure and infrastructure access between regions.

However, when making a preliminary assessment of the distribution of the data set using the Explore method, the author found that the distribution curve of all variables in the research model did not approach the normal distribution, and there were outliers that could distort the research results. Therefore, to minimize the bias in the research results, the author used the logarithmic method to reduce the data dimension for the above factors. From there, the study found new variables corresponding to LnWAT, LnPUB, LnPRD, LnFDI, LnGPC, LnPOP.

Table 4: Sample descriptive statistics results after transformation (n=70)

Variables	Mean	S.D	Min	Max
LnWAT	4.49	.12	4.07	4.61
LnPUB	15.20	.37	14.28	16.08
LnPRD	15.71	.67	14.26	17.03
LnFDI	11.56	3.40	4.96	16.81
LnGPC	10.83	.33	10.25	11.63
LnPOP	4.89	.69	3.93	6.20

Source: Data analysis by SPSS 27

The post-transformation statistical results show that all variables have a lower standard deviation than the original data, indicating more uniformity and stability. Specifically, the LnWAT variable has a mean value of 4.49 and a standard deviation of only 0.12, indicating a relatively tight distribution and little variation in the level of access to clean water among localities in the survey sample. Similarly, the LnPUB, LnPRD and LnGPC variables all have standard deviations less than 0.7, reflecting a moderate level of variation after adjustment. Notably, the LnFDI variable, although logarithmized, still has a fairly large standard deviation (SD = 3.40), indicating a significant difference between provinces in attracting foreign direct investment. This is consistent with the reality when FDI is often concentrated in some localities with more favorable socio-economic conditions. The LnPOP variable representing urban population density also has a moderate standard deviation (0.69), reflecting certain differences in population characteristics among the northern mountainous provinces.

4.3 Research model assessment results

After ensuring that the data had a normal distribution, the author performed a multivariate regression analysis using the Casewise Diagnostics method to eliminate outliers. By selecting 3 standard deviations, this method will detect which observations have residuals that are 3 standard deviations or more from the mean. These are considered to be the cases with the largest errors and are predicted to be outliers that cause bias for the research results.

Table 5: Casewise diagnostics result

Case Number	Std. Residual	LnWAT	Predicted Value	Residual
1	-3.167	4.07	4.3357	-.26156
a. Dependent Variable: LnWAT				

Source: Data analysis by SPSS 27

In the first multiple regression analysis, the Casewise Diagnostics method suggested that observation case number 1 might be an outlier in the data set. Accordingly, the author will consider removing these observed variables and re-testing the regression model a second time to examine the reasonableness of the research results. However, after removing the observed variables and testing the regression model, the research results showed that some statistical relationships were lost, as well as the explanatory power of the research model was reduced. Therefore, the author still kept the research model with the original data set.

Table 6: ANOVA result (n=70)

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.579	5	.116	16.981	.000[b]
Residual	.436	64	.007		
Total	1.016	69			
a. Dependent Variable: LnWAT					
b. Predictors: (Constant), LnPOP, LnPUB, LnGPC, LnPRD, LnFDI					

Source: Data analysis by SPSS 27

Table 6 presents the results of the ANOVA test for the regression model. The F value of the model is 16.981 with a p-value (Sig.) of 0.000, less than 0.01, indicating that the model is highly statistically significant. In other words, the

independent variables included in the model have a significant impact on the dependent variable, i.e. access to clean water in the provinces of the Northern Midlands and Mountains region of Vietnam.

Table 7 presents a summary of the linear regression model results, showing the level of fit between the model and the research data. The R Square value = 0.570 shows that the model explains 57% of the variation in access to clean water in the northern mountainous and midland provinces, through factors of investment and socio-economic conditions. When adjusting for the number of variables in the model, the Adjusted R Square slightly decreased to 0.537, but still showed a good level of explanation. The standard error of the estimate is low (0.08258), showing that the dispersion between the actual value and the forecast value is not large. The Durbin-Watson index = 1.560 is in the range of 1.5 to 2.5, which is an acceptable level showing that there is no significant autocorrelation in the residuals, helping to ensure the accuracy and reliability of the model.

Table 7: Model summary (n=70)

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
.755[a]	.570	.537	.08258	1.560
a. Predictors: (Constant), LnPOP, LnPUB, LnGPC, LnPRD, LnFDI				
b. Dependent Variable: LnWAT				

Source: Data analysis by SPSS 27

The study also tested for multicollinearity using the VIF (Variance Inflation Factor) index. The results in Table 8 showed that all variables had VIFs less than 10 specifically: LnPUB (2.061), LnPRD (2.547), LnFDI (2.797), LnGPC (2.033), and LnPOP (3.877). According to the popular threshold proposed by Hair et al. (2010), a VIF value < 10 is acceptable and indicates that there is no serious multicollinearity in the model.

The results show that the standardized coefficient β of LnPUB is -0.322 and is statistically significant with sig. or p-value = 0.008 (< 0.05). This means that public investment has a significant negative impact on the level of access to clean water in the study area. This result may reflect the low efficiency or unreasonable allocation of public investment in water supply infrastructure, or delays in implementation, especially in areas with complex terrain. Accordingly, hypothesis H1 "Public investment capital has an impact on the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam" is supported.

Table 8: Estimated coefficient analysis results (n=70)

	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	VIF
	B	Std. Error				
(Constant)	2.671	.545		4.903	.000	
LnPUB	-.106	.039	-.322	-2.741	.008	2.061
LnPRD	.024	.024	.129	.990	.326	2.547
LnFDI	.010	.005	.281	2.047	.045	2.797
LnGPC	.281	.043	.764	6.540	.000	2.033
LnPOP	-.022	.028	-.123	-.765	.447	3.877
a. Dependent Variable: LnWAT						

Source: Data analysis by SPSS 27

The standardized coefficient β of LnPRD is 0.129, but it is not statistically significant (p-value = 0.326 > 0.05). Although the impact sign is positive, there is not enough basis to confirm that domestic private investment has a significant impact on the clean water supply situation in this area. Accordingly, hypothesis H2 " Private domestic investment capital has an impact on the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam" is not supported.

The standardized coefficient β of LnFDI is 0.281 and is statistically significant at p-value = 0.045 (< 0.05), indicating that FDI has a positive and significant impact on access to clean water. Accordingly, hypothesis H3 “Foreign direct investment capital has an impact on the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam” is supported.

The results also show that the LnGPC variable has a fairly high standardized coefficient β (0.281) and strong statistical significance (p-value = 0.000), indicating that places with higher income levels have better access to clean water, which is completely reasonable from an economic perspective. Meanwhile, the population density variable LnPOP has a negative standardized coefficient β and has no statistically significant impact (p-value = 0.447), indicating that population density has not had a significant impact on the level of access to clean water in this model.

4.4 Discussion of results

Firstly, the study found a negative impact of public investment capital on the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam. This result is contrary to that by Greer (2020) and Toan et al. (2023). Although this result may be surprising, it is a warning sign about the effectiveness of public investment capital, especially in the context of localities with complex terrain conditions, scattered population and high investment costs. In fact, many water supply works built with state budget capital in mountainous areas have rapidly deteriorated or ceased to operate after a short time, due to lack of maintenance or poor operation. This is consistent with reports from the Ministry of Agriculture and Rural Development showing that the rate of effective rural water supply systems is only about 30-40%, the rest are unstable or damaged. Thus, although public investment is intended to guide and support vulnerable groups, if there is a lack of effective monitoring and enforcement mechanisms, this resource can become a financial burden without bringing about the desired results.

Secondly, the study does not find out the relationship between private domestic investment and the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam. The result goes against the study by Anh et al. (2022) and Nguyen et al. (2023). Domestic private investment has not had a clear impact on access to clean water in the northern mountainous region. The reasons may stem from a number of factors such as the lack of effective investment incentive mechanisms, such as tax incentives, credit support or risk sharing. In addition, there are difficulties in capital recovery and low profits in rural areas, rugged terrain, and sparse population. At the same time, market demand is fragmented, not attractive enough for businesses to invest long-term.

Thirdly, foreign direct investment capital has an positive impact on the current status of clean water supply in the Northern Midland and Mountainous Region of Vietnam. This result is completely consistent with international theory and practice by Aust et al. (2020) and Irene (2022), because foreign investors often bring modern technology, advanced management processes and higher environmental standards, contributing to improving the operational efficiency and quality of water supply systems. In particular, aid and development cooperation programs from international organizations (such as JICA, GIZ, KOICA...) play an important role in improving access to clean water in disadvantaged areas of Vietnam. However, FDI in the water supply sector in the Northern mountainous region is still limited, due to low profits and poor infrastructure conditions. Therefore, this positive result is an important suggestion for management agencies in attracting socialized FDI, combining profits and sustainable development goals, especially in support programs for remote areas.

From a policy perspective, higher incomes often go hand in hand with local economic development and more synchronous infrastructure investment, making it easier for the state and businesses to implement centralized or semi-centralized water supply projects. Provinces such as Thai Nguyen, Bac Giang, and Phu Tho - where per capita incomes are higher, also have a higher proportion of households using clean water, because they can afford to pay for tap water, invest in water filtration systems, tanks, or use services provided by businesses. On the contrary, in Lai Chau, Dien Bien, and Ha Giang provinces, despite having many state support projects, due to low incomes, many households still depend on natural, untreated water sources, increasing the risk of disease and affecting the quality of life.

The results show that population density does not have a significant impact on access to clean water in the model. While in the plains and large urban areas, high population density is often accompanied by better infrastructure, in mountainous areas, although some places are classified as "urban", the scale is very small, scattered, and the water supply system is very limited, not enough to serve the entire population. In addition, the complex, mountainous, and fragmented terrain makes it difficult and costly to install clean water pipes even though the population is concentrated, affecting investment efficiency. Some type IV or V urban areas in provinces such as Lao Cai, Tuyen Quang, and Ha Giang have a high population density, but the rate of households using clean water is still low due to lack of investment capital and difficulties in operating the water supply network.

5. IMPLICATIONS AND CONCLUSION

Through a mixed research method using in-depth interviews with managers and local residents, along with secondary data collected during the period 2020-2024, the study makes some important academic contributions as follows. Firstly, this study extends and tests the public investment theory (Musgrave, 1959) in the context of localization in the Northern Midlands and Mountains region of Vietnam. While traditional theory suggests that public investment plays a key role in providing public services to disadvantaged groups, empirical research results indicate that public investment has a negative impact on the level of access to clean water in the study area. This finding adds a new perspective to the theory, that the effectiveness of public investment depends not only on the scale of investment but also largely on the implementation efficiency, the way of capital allocation, terrain conditions and local management capacity. Secondly, the study contributes to the endogenous growth theory (Romer, 1990; Barro, 1991) by clarifying the differentiated role of each type of investment capital in the development of public service infrastructure, specifically the clean water supply system. The results show that FDI capital has a clear positive impact on access to clean water, while domestic private capital has not shown a clear impact, and public capital even has a negative impact. This suggests that in theoretical growth models, it is necessary to distinguish the role and efficiency between types of investment capital, and integrate local context factors to more accurately reflect the

impact of investment on basic infrastructure development. Thirdly, the study has academic value in analyzing three types of investment capital separately - public, domestic private and FDI - instead of just using total investment as many previous studies. Measuring and directly comparing the impact of each capital source helps to specify the different operating mechanisms of each type of investment on the water supply system. This is an important contribution to the research direction of public service infrastructure development, suggesting further research models on how to build a multidimensional analytical framework that is more suitable to the practices of developing countries. Finally, by including control variables such as GRDP per capita and population density, this study further elucidates the relationship between people's economic capacity and access to clean water. The results show that income is strongly correlated with access to clean water, while population density has no significant effect. This is a significant theoretical contribution in expanding the understanding of factors affecting public services, showing that access to services depends not only on population density but also on affordability and distribution infrastructure at each locality. Some urban areas of class IV or V in provinces such as Lao Cai, Tuyen Quang, and Ha Giang have high population density, but the proportion of households using clean water is still low due to lack of investment capital and difficulties in operating the water supply network.

The study results indicate that public investment has a significant negative impact on access to clean water in the Northern Midland and Mountainous region of Vietnam. This raises an urgent need to review the allocation and implementation of public investment in this region. The reasons may be due to delays in disbursement, scattered investment, or lack of suitability with the complex terrain characteristics of the region. Therefore, the Ministry of Finance needs to coordinate with the People's Committees of the provinces in the region to evaluate the effectiveness of water supply projects using state budget capital. At the same time, it is necessary to consider converting the form of investment from completely public to PPP to both take advantage of private resources and ensure the efficiency of project operation.

A bright spot in the research results is that foreign direct investment shows a positive and statistically significant impact on the level of access to clean water. This is an important basis for recommending that the government, especially the Ministry of Finance, prioritize attracting FDI into this sector. In the context of Vietnam promoting integration and transitioning to a green economy, creating favorable conditions such as tax exemptions, land access support, and quick investment procedures will help attract foreign investors to difficult areas such as the Northern mountainous region. In addition, the participation of international organizations such as JICA, KOICA or GIZ with technical and financial assistance programs should also be promoted to expand the water supply network in remote areas.

Another notable result is that the control variable GRDP per capita has a negative impact on access to clean water. Although it may be surprising, this reflects the fact that localities with higher incomes do not necessarily have better water supply systems, especially if these regions focus on economic development at the expense of basic infrastructure investment. In addition, the complex terrain of mountainous areas also makes access to clean water difficult, even in places with high GRDP index. The government needs to develop zoning policies to prioritize clean water infrastructure investment, focusing on low-income areas combined with difficult terrain conditions. At the same time, it is possible to consider applying micro water systems or water treatment technologies suitable for household scale in scattered residential areas.

The study results confirm that GRDP per capita has a positive and strong impact on access to clean water. This is consistent with economic logic: when income increases, people are willing to pay for higher quality clean water services. However, this also poses challenges for low-income groups who have difficulty accessing clean water services due to system investment costs or usage costs. Therefore, the government and localities need to have policies to support dual goals: (1) improving people's income capacity through training and livelihood development; and (2) subsidizing or supporting initial investment in clean water systems in low-income areas. This will ensure equity in access to clean water and gradually reduce the gap between population groups.

A notable point from the qualitative research results is the clear difference between household groups in terms of access to clean water, especially in high terrain or remote areas where water shortages or no water pipes to households often occur. Meanwhile, local authorities have a relatively positive assessment, showing that there is a certain gap between policy and practice. This raises an urgent need to develop specific water supply policies, "localized" according to specific terrain, population and infrastructure conditions. Uniform models applied to the entire region are no longer suitable; instead, it is necessary to encourage the implementation of flexible solutions such as household-scale filtration systems, rainwater tanks, small-scale water supply models suitable for terrain conditions, or the use of renewable energy (such as solar power) to operate water pumps in high-altitude areas. At the same time, to ensure that these policies are put into practice, it is necessary to strengthen the community's feedback and monitoring mechanisms through channels such as incident reporting applications, periodic surveys on people's satisfaction with clean water services, or organizing dialogue forums at the commune/district level. These solutions not only help to promptly detect shortcomings in the policy implementation process but also contribute to improving transparency, accountability and investment efficiency in the long term.

This study still has certain limitations. First, the use of short-term provincial-level secondary data may not fully

reflect actual factors at the household level such as satisfaction, stability or quality of water used, which may affect the accuracy of the impact assessment of investment capital sources. Therefore, future studies should incorporate primary surveys in the community to supplement qualitative and quantitative depth. Second, the research model does not consider geographical factors while in reality, there are clear differences between lowland and highland areas in terms of access to clean water. Therefore, future studies should apply spatial analysis methods to assess the impact of terrain and natural conditions to develop more appropriate policy recommendations for each region.

6. ACKNOWLEDGMENT

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