



FOREIGN DIRECT INVESTMENT, EXPORT STRUCTURE, AND VIRTUAL WATER FLOWS: A MULTI-COUNTRY INPUT-OUTPUT ANALYSIS OF WATER RESOURCE PRESSURES FROM INTERNATIONAL TRADE

Dr.Sajitha P K

Associate Professor, Department of Economics, Sir Syed College, Affiliated to Kannur University, Taliparamba, Kannur, Kerala, E-mail: sjayakrish@gmail.com

Received: 09/12/2025 Revised: 10/01/2026 Acceptance: 18/01/2026 Published: 25/01/2026

Abstract

Water stress is increasingly recognized as an economic and investment risk, yet its longitudinal relationship with foreign direct investment (FDI) remains insufficiently understood. This study examined whether water stress, calendar year, and World Bank income group predicted FDI inflows across countries from 2000 to 2022. A quantitative longitudinal panel design used 4,991 country-year observations from the World Development Indicators. FDI inflows as a percentage of GDP were modeled as the dependent variable, while water stress, centered year, and income-group code were entered as fixed effects, with country specified as a random intercept. Extreme values were winsorized at the 1st and 99th percentiles. Descriptive statistics, Pearson correlations, multicollinearity diagnostics, null and adjusted mixed-effects models, residual diagnostics, and REML–ML robustness comparisons were performed in SPSS 26. Water stress showed a small negative but nonsignificant association with FDI ($B = -0.003886$, $p = .198$), and year was also nonsignificant ($B = -0.012240$, $p = .574$). Income group had a significant positive effect ($B = 1.625317$, $p = .006$). The ICC was 0.597, indicating substantial between-country variation. The findings suggest that national structural conditions directly influence FDI more strongly than water stress alone.

Keywords: Foreign direct investment, Water stress, Mixed-effects model, Panel data, Sustainable development

1. Introduction

Foreign direct investment (FDI) is one of the major sources of capital, transfer of technology, employment generation, increase in productivity and international economic integration. It allows host countries to increase the productive potential of their resources and to multinational enterprises to gain access to markets, resources and strategic location. The choice of investment location, however, is also increasingly affected by factors which reflect environmental risks and resource availability, as well as by the traditional factors that relate to the size of the market, infrastructure, labor cost and institutional quality. There is a growing trend in the recent investment climate for considering sustainability, climate resilience and resource security in country development policies and foreign investment decision making (United Nations Conference on Trade and Development, 2024).



Water is a key strategic commodity as the production of agricultural crops, manufacturing, energy generation, mining, transportation and urban development are all water dependent. This can have a negative impact on production costs, the continuity of the production chain, regional competitiveness and on the long-term viability of investments. The economic benefits of water are not just limited to its direct use, but it also provides benefits for ecosystems, public health, productivity of labour and social stability (Garrick et al., 2020). However, water scarcity is increasingly aggravated by a number of factors such as increasing need for freshwater, climate change, population growth, urbanisation and poor resource management in many regions of the world. Overall, water stress has emerged as a key constraint to sustainable development. The pressure on developed and developing economy is due to increased withdrawals and decreased water quality, as well as unequal access to fresh water. The water shortage is not just a problem in dry areas; the fast pace of urbanisation and increasing industrial needs are resulting in water shortages in many large cities and production hubs (He et al., 2021). Such pressures can affect investment decisions by making operations riskier and could lead to rethinking the location of water-intensive operations. Therefore, it is crucial to understand the link between water stress and FDI to ensure the economic growth is in line with sustainability.

Water stress broadly is an indicator of how much pressure water withdrawals bear on the renewable freshwater resources. Typically, it's calculated as the percentage of total freshwater withdrawals from the total freshwater resources. Water stress is high, meaning that countries are relying on a significant proportion of their renewable water resources, which may lead to greater vulnerability to water shortages, environmental degradation and water conflicts among agricultural, industrial and domestic water users (United Nations Environment Programme, 2021). Water stress can have significant economic impacts, varying from country to country. Water shortages can lead to lower crop production, restrict industrial production, higher energy and treatment costs and restrict urban growth. It might also involve an investment by governments and businesses in water-storage facilities, recycling and desalination, water conservation and efficiency improving technologies. Consequently, the economic impacts will vary, depending on institutional capacity and technological adaptation as well as trade relations and the structure of national economies (Damania, 2020).

Additionally, water-quality degradation exacerbates water scarcity as technically available water may not be suitable for productive or domestic purposes. If water quality is also taken into account, the number of areas experiencing 'effective' water scarcity is significantly higher (Jones et al., 2024). The economic impacts of water shortages in the future can also be highly country-specific due to the complex interplay between water scarcity and climate change, consumption, infrastructure and adaptive capacity (Dolan et al., 2021). Water stress can bring physical, regulatory, operational and reputational risks for multinational companies. Companies in areas with significant stress can be subject to production disruptions, increased input costs, community disputes, and/or more stringent environmental laws. The geographical exposure and long-term security of international investment is therefore becoming more and more relevant in the context of climate change (Li & Gallagher, 2022).

Past studies have confirmed that water shortage can affect the growth, productivity, urban development and economic output. Water shortages have been predicted to have differential economic impacts; in countries with limited ability to adapt, strong economic impacts are expected, whereas in other countries economic impacts may be weaker (Dolan et al., 2021). Furthermore, integrated evaluations, in which water quality is considered, suggest that traditional water-related development constraint assessments may be underestimating the actual challenges of water constraints on



development (van Vliet et al., 2021). Nevertheless, empirical evidence on the effect of water stress on FDI is still scarce.

Most research focuses on the climate exposure of the recipient country, the recipient country's economic growth or overall water scarcity and does not assess systematically if and how water stress affects FDI inflows across countries over time. Unobserved country-specific characteristics and income group differences are also underrepresented in the previous studies. This is crucial as the impact of water stress in deterring or encouraging investment, and adaptive infrastructure and technological innovation, may depend on national income and development capacity. The overall investment environment of low, middle and high income economies could potentially impact investment outcomes and resilience to environmental pressures (World Bank, 2024).

Research Objectives

This study has three objectives:

- to investigate the relationship between water stress and FDI inflows
- to analyse the temporal variation for the period from 2000 until 2022
- to analyse the differences between the various World Bank income levels and quantify country-level variation with a mixed-effects model

Research Hypotheses

H0₁: Water stress has no significant association with FDI

H1₁: Water stress significantly influences FDI

H0₂: Calendar year has no significant effect on FDI

H1₂: Calendar year significantly influences FDI

H0₃: Income group has no significant effect on FDI

H1₃: Income group significantly influences FDI

2. Materials and Methods

The FDI data were obtained from the World Development Indicators database (World Bank, 2026a), water-stress data were obtained from the World Development Indicators database (World Bank, 2026c), and income-group classifications were based on the World Bank country and lending groups framework (World Bank, 2026b).

sAnalytical structure was a series of observations made annually at the same time point, within countries which enabled the examination of both temporal variation and country-level heterogeneity. The operational definitions of the key variables are shown in Table 1.

Table 1. Study Variables and Operational Definitions

Variable	Role	Operational definition
Foreign direct investment	Dependent variable	Net FDI inflows expressed as a percentage of gross domestic product



Water stress	Independent variable	Freshwater withdrawals expressed as a proportion of available freshwater resources
Calendar year	Covariate	Annual observation period from 2000 to 2022
Income group	Covariate	World Bank country classification based on income level
Country	Random effect	Country-level clustering variable identified using country codes

A data preparation process was undertaken which involved checking for missing values, extreme observations, coding of variables and transformation of variables. All data were examined for missingness and those with any data missing for the variables included in each model were not included. The values of foreign direct investment and water-stress were found to be highly skewed with extreme observations and hence both were winsorised at the 1st and the 99th percentile. This way the extremes were not given too much weight while maximizing the use of the observations. By subtracting out 2000 from each year, each value was centred, which gave a range of values from 0 to 22.

Numerical coding was used for income groups for the statistical model and coding for country codes was used for panel structure. Descriptive statistics were used such as the mean, standard deviation, minimum, maximum, skewness and kurtosis. Patterns of missing data were checked prior to the analysis of the data at an inferential level. Pearson correlation coefficients were used to determine bivariate relationships between variables of FDI, water stress and year. Tolerance and variance inflation factor statistics were used to check for multicollinearity. The estimation of a null random-intercept mixed model was used first to break down the FDI variance between countries and within countries.

Intraclass correlation coefficient was then used to estimate the percentage of the total variance between the countries. The primary LME model comprised of water stress as a fixed effect, and a random intercept by country and a centred year effect as fixed effects. The primary model was using the restricted maximum likelihood estimation. The residual distribution, normal Q – Q plot and residual – predicted plot were used to evaluate the model assumptions. The same model was re-estimated by maximum likelihood for a robustness check and the maximum likelihood coefficients, significance and variance estimates were compared to the restricted maximum likelihood estimates. IBM SPSS Statistics, version 26 software was used for all statistical analysis.

3. Results

A total of 4,991 observations by country-year spanning from 2000 to 2022 were analysed. The results are presented in sequence, descriptive statistics, evaluation of missing data, winsorization of data, correlation analysis, multicollinearity diagnostics and finally linear mixed-effects modelling. The numbers below were simply copied out of the SPSS output.

3.1 Descriptive Statistics



There was considerable variation and strong positive skewness of the original variables. 4,432 was the number of valid observations for FDI as percentage of GDP and 3,953 was the number of valid observations for water stress. Descriptive characteristics of the original variables are given in table 1.

Table 1. Descriptive Characteristics of the Original Study Variables

Variable	Valid N	Missing N	Mean	SD	Minimum	Maximum	Skewness	Kurtosis
FDI inflows (% of GDP)	4,432	559	9.2142	63.33152	-1303.11	1709.83	10.859	278.063
Water stress (%)	3,953	1,038	65.6484	279.94909	0.03	3850.50	9.096	96.069
Calendar year	4,991	0	2011.0000	6.63391	2000	2022	0.000	-1.205
Income-group code	4,991	0	2.9493	1.03507	1	4	-0.522	-0.976

There was very large positive and negative observations that led to extremely high skewness and kurtosis for the FDI variable. The water stress values were also highly positively skewed, with extreme values. In contrast, the distributions of year and income group were relatively similar.

3.2 Missing Data Pattern

The variables that contained missing values had a large proportion of them in the FDI and water-stress variables. The percentage of missing observations in FDI was 11.2% (559 missing observations) while water stress had 20.8% (1,038) missing observations. No data were missing for the year and income-group code. The number of complete observation in the main mixed-effects model was 3,835 (76.8% of original observations). Thus 1,156 observations (23.2%) were dropped due to the absence of at least one of the model variables.

The missing-data pattern is illustrated in Table 2.

Table 2. Missing Data Patterns in the Panel Dataset

Pattern	Year	Income Group	FDI (% of GDP)	Water Stress	Number of Cases	Complete Cases if Pattern Excluded
1	Available	Available	Available	Available	3835	3835
2	Available	Available	Available	Missing	597	4432



3	Available	Available	Missing	Missing	441	4991
4	Available	Available	Missing	Available	118	3953

Note. Patterns representing fewer than 1.0% of observations (≤ 50 cases) are omitted, following the default SPSS Missing Value Analysis (MVA) output. The "Complete Cases if Pattern Excluded" column indicates the number of observations available if variables with missing values in the corresponding pattern are excluded from the analysis.

As seen in Table 2, there was no missing data for year and income-group classification while there was missing data in FDI and water stress. The greater percentage of missing data for water stress was the main reason for the lower amount of data for analysis.

3.3 Distribution Before and After Winsorization

Winsorization was done at the 1st and 99th percentiles. The lower and upper cut-off values of FDI were -6.6852 and 124.6264 , respectively. The cut-offs of water stress were 0.1322 and 1606.3467 . The mean FDI value after winsorization was 6.0459 , and the standard deviation value was 14.58968 , both of which decreased after the winsorization procedure. The mean water-stress value declined from 65.6484 to 57.0164 , and its standard deviation declined from 279.94909 to 194.36625 . This information is provided in Table 3.

Table 3. Descriptive Statistics Before and After Winsorization

Variable	Condition	N	Mean	SD	Minimum	Maximum	Skewness	Kurtosis
FDI (% GDP)	Original	4,432	9.2142	63.33152	-1303.11	1709.83	10.859	278.063
FDI (% GDP)	Winsorized	4,432	6.0459	14.58968	-6.69	124.63	6.423	46.774
Water stress (%)	Original	3,953	65.6484	279.94909	0.03	3850.50	9.096	96.069
Water stress (%)	Winsorized	3,953	57.0164	194.36625	0.13	1606.35	6.591	46.107

The distributions before and after winsorization are presented in Figure 1.

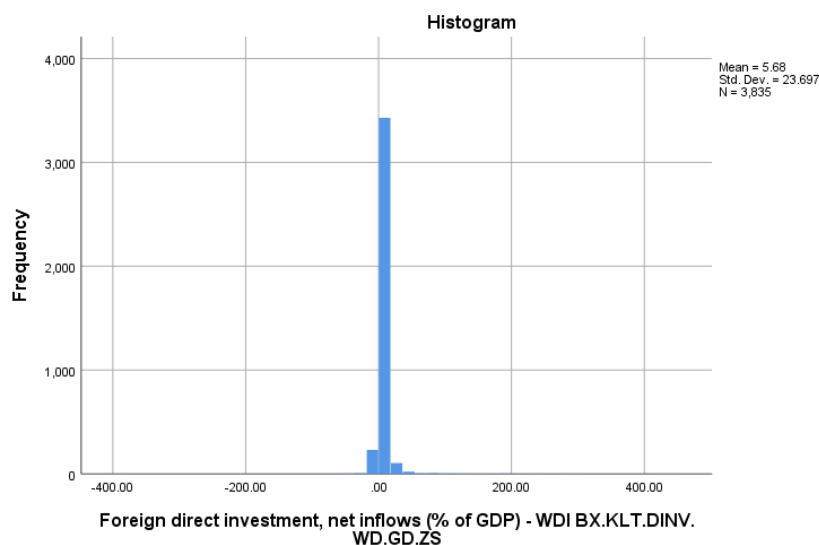


Figure 1. Distribution of FDI and Water Stress Before and After Winsorization

The ranges and dispersions were greatly reduced as a result of winsorization, as seen in Figure 1. But, both of these distributions were still positively skewed, as there were several fairly large values still within the defined percentile range.

3.4 Pearson Correlation Analysis

Pearson correlations were calculated using pairwise-valid observations. Table 4 presents the correlation coefficients, significance levels, and sample sizes.

Table 4. Pearson Correlation Matrix

Variable	1	2	3
1. Winsorized FDI	1		
2. Winsorized water stress	-0.040*	1	
3. Calendar year	-0.009	-0.005	1

Note. FDI–water stress: N = 3,835; FDI–year: N = 4,432; water stress–year: N = 3,953.
* p = .013.

There was a negative correlation between winsorized FDI and water stress which, although statistically significant, was negligible ($r = -.040$, $p = .013$). There was not a significant correlation between FDI and year, $r = -.009$, $p = .567$. No significant correlation between water stress and year was found either ($r = -.005$, $p = .735$).

3.5 Multicollinearity Assessment

Tolerance and variance inflation factor statistics were examined before fitting the mixed-effects model. The results are presented in Table 5.

Table 5. Multicollinearity Diagnostics



Predictor	Tolerance	VIF
Winsorized water stress	0.970	1.031
Calendar year	1.000	1.000
Income-group code	0.970	1.031

All the tolerance were >0.90 , and all the variance inflation factors (VIF) were close to 1.00. The results show that there was no multicollinearity between the predictors. The high condition index that was obtained with the original year variable could be explained by the high numerical range of this variable. This resulted in a centred variable with a mean value of 11.00, a standard deviation of 6.634 and a range of 0 to 22 and year centred at 2000.

3.6 Null Mixed Model

To see if FDI varied systematically across countries an intercept-only random-intercept model was estimated. The null model produced an estimated overall intercept of 6.163754, $SE = 0.829239$, $t(200.679) = 7.433$, $p < .001$, with a 95% confidence interval from 4.528615 to 7.798893.

The variance components and calculated intraclass correlation coefficient are presented in Table 6.

Table 6. Variance Components and Intraclass Correlation from the Null Model

Component	Estimate	SE	Wald Z	<i>p</i>	95% CI
Between-country variance	134.145583	13.850614	9.685	$<.001$	109.569402–164.234147
Residual variance	90.634812	1.970751	45.990	$<.001$	86.853362–94.580901
Intraclass correlation coefficient	0.597	—	—	—	—

The intraclass correlation coefficient was equal to 0.597 with an approximately 59.7% of the total variance in winsorized FDI coming from between countries. The rest (40.3%) was year-to-year variation within countries. The large amount of clustering justified a random-intercept model for the country-level analysis.

3.7 Main Mixed-Effects Model

A random intercept for country was added to the main RML model that was fitted with fixed effects for the winsorized water stress, the centred year and the income-group code. The results of fixed-effect estimates are presented in Table 7.

Table 7. Fixed-Effect Estimates from the REML Mixed-Effects Model

Predictor	Estimate	SE	df	<i>t</i>	<i>p</i>	95% CI
-----------	----------	----	----	----------	----------	--------



Intercept	0.985978	1.724165	181.866	0.572	.568	-2.415962– 4.387918
Water stress	-0.003886	0.003010	201.683	-1.291	.198	-0.009821– 0.002048
Centred year	-0.012240	0.021746	3676.990	-0.563	.574	-0.054876– 0.030396
Income-group code	1.625317	0.578996	175.169	2.807	.006	0.482610–2.768024

Water stress did not significantly predict FDI, $F(1, 201.683) = 1.667, p = .198$. The coefficient showed that an increase of one unit in water stress led to an average decrease in FDI of 0.003886 unit and the 95% confidence interval contained 0. Centred year was also nonsignificant, $F(1, 3676.990) = 0.317, p = .574$. Hence, it can be concluded that there were no major linear temporal variation in the FDI during the study period. Fixed-effect income-group code was the only one to be statistically significant, $F(1, 175.169) = 7.880, p = .006$. An additional income-group code was estimated to correspond to an additional 1.625317 percentage-point change in winsorized FDI, controlling for water stress, year and country-level clustering. All the three null hypotheses for water stress, year and income group were not accepted except the latter.

3.8 Random Effects

Country-level heterogeneity remained statistically significant after the fixed predictors were included. Table 8 presents the variance components of the final REML model.

Table 8. Random-Effect Variance Components from the REML Model

Component	Estimate	SE	Wald Z	p	95% CI
Between-country intercept variance	57.795459	6.592809	8.766	<.001	46.216385– 72.275560
Residual variance	76.259606	1.782577	42.781	<.001	72.844645– 79.834662

The intercept variance for the country-level decreased from 134.145583 (null model) to 57.795459 (adjusted model). However, it was still statistically significant and showed that there are still significant differences in FDI across countries when controlling for the variables of water stress, year and income group.

3.9 Comparison of REML and ML Models

The final model was re-estimated using maximum likelihood to examine whether the results were sensitive to the estimation method. Table 9 compares the REML and ML estimates.



Table 9. Comparison of REML and ML Mixed-Effects Estimates

Parameter	REML estimate	REML <i>p</i>	ML estimate	ML <i>p</i>
Intercept	0.985978	.568	0.986255	.565
Water stress	−0.003886	.198	−0.003887	.195
Centred year	−0.012240	.574	−0.012240	.574
Income-group code	1.625317	.006	1.625254	.005
Between-country variance	57.795459	<.001	56.777316	<.001
Residual variance	76.259606	<.001	76.236783	<.001

The values of the REML and ML were very close. Income-group code was found to be statistically significant while water-stress and year were nonsignificant. Thus, there was consistent (substantive) evidence across both estimation procedures. The REML model produced a -2 restricted log likelihood of 28014.582, AIC of 28018.582, and BIC of 28031.083. The ML model produced a -2 log likelihood of 28000.474, AIC of 28012.474, and BIC of 28049.986. However, these information criteria should not be directly interpreted as proof of better performance of ML compared to REML because different definitions of likelihood were used in the estimation of the models.

3.10 Model Diagnostics

Residual diagnostics were performed with the 3,835 observations that ended up in the final model. The mean of the residual was 0.000000 with the standard deviation of the residual being 8.542741. Residual values ranged from -76.7629 to 98.4627. It was positively skewed with a value of 2.331 and positively kurtic with a value of 37.611.

The residual histogram is presented in Figure 2.

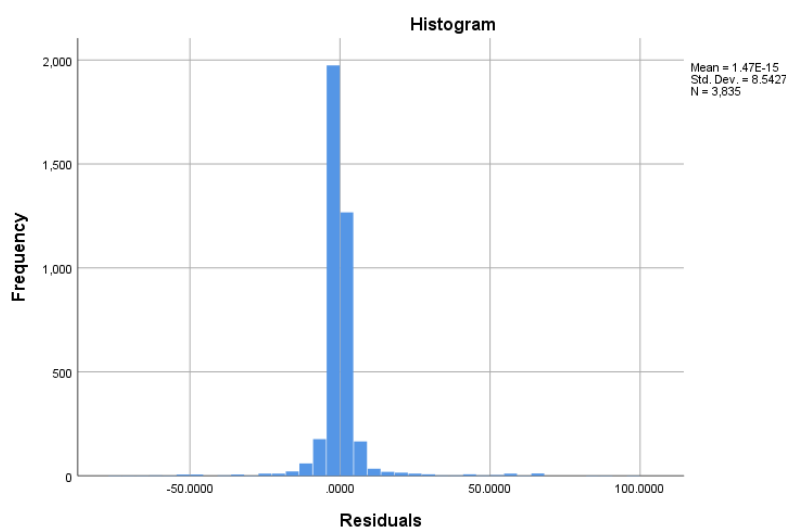


Figure 2. Histogram of Residuals from the Final Mixed-Effects Model



Figure 2 shows that the residuals were centred near zero, but had a positive "tail" and they were heavy-tailed. There were several positive and negative residuals that were large, meaning that there were some country year observations that were not well predicted by the model.

The normal Q–Q plot is presented in Figure 3.



Figure 3. *Normal Q–Q Plot of Model Residuals*

As seen in figure 3, there are deviations from the diagonal reference line (mainly in the tails). Formal normality tests were also significant: Kolmogorov–Smirnov statistic = .252, $df = 3,835$, $p < .001$, and Shapiro–Wilk statistic = .511, $df = 3,835$, $p < .001$. Thus, the assumption of normality of the residuals was not met.

The residual-versus-predicted plot is presented in Figure 4.

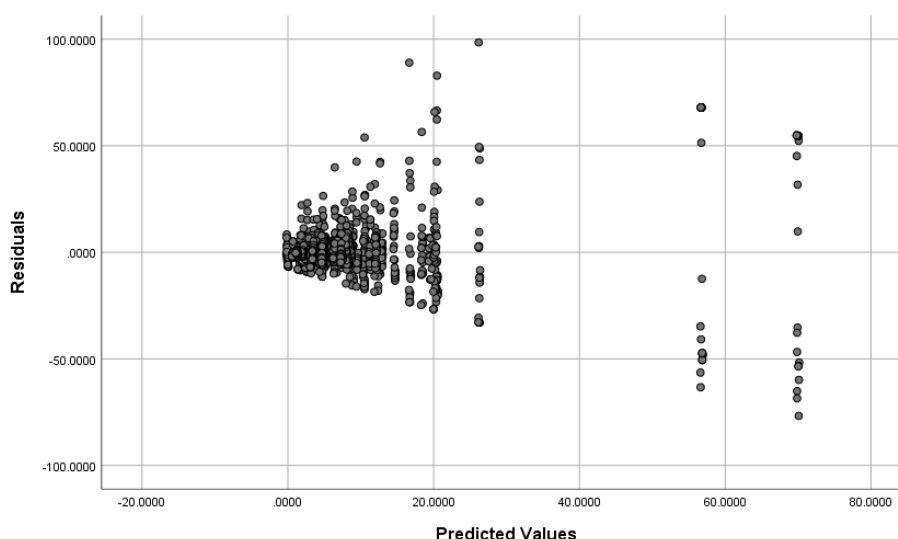


Figure 4. *Residuals Versus Predicted Values from the Final Mixed-Effects Model*

Residuals were generally scattered above and below zero, there was no apparent curved pattern and the specification was approximately linear, supporting this conclusion. The dispersion of residuals, however, was different based on the predicted values, which meant there was some heteroscedasticity; and there were a few extreme values of the residuals represented. The overall fit of the model was



good, but there was some non-normality in the residuals from the model, heavy tails, and a mild heteroscedasticity.

Hypothesis-wise synthesis showed that H_{01} was not rejected, as water stress had a small negative but nonsignificant effect on FDI ($B = -0.003886$, $p = .198$). H_{02} was also not rejected, because calendar year did not significantly predict FDI ($B = -0.012240$, $p = .574$). In contrast, H_{03} was rejected and H_{13} was supported, as income group had a significant positive effect on FDI ($B = 1.625317$, $p = .006$), indicating that higher-income countries attracted greater FDI relative to GDP.

4. Discussion

In the present study, the longitudinal association between water stress and FDI was assessed in 2000–2022 for countries, using a random-intercept mixed-effects model. The results revealed that water stress was slightly negatively, but not statistically significantly, associated with FDI with estimated coefficient of -0.003886 and a statistically non-significant p value of $.198$. The variables year (calendar year) was also found not significantly associated with FDI but positive effect of national income-group classification was significant. The positive effect of an additional category (one level higher) in the income-group code on FDI in percentage of GDP was estimated to be 1.625 percentage points. In addition, the ICC of 0.597 indicated that about 59.7% of the total variation in FDI was due to the variations among countries. Confidence in the consistency of these results was high because the RML and ML estimates for these parameters were very similar.

When compared with income level, time and persistent country level characteristics, the results indicate that water stress is not directly associated with FDI inflows as the association is not significant. While water scarcity can impact production costs, supply chains and uncertainty for water dependent industries foreign investment decisions are made based on the size of the market, institutional quality, availability of labour, infrastructure, taxation, political stability and access to trade. Thus, the economic effects of water stress could be indirect via a loss in productivity, exposure of certain economic sectors, or infrastructure restrictions, but not necessarily through a decrease in overall FDI. Water pricing and allocation systems can also affect the ability of countries to deal with water scarcity effectively, and similar water stress levels can result in different economic outcomes, depending on the water governance and policy responses (Grafton et al., 2020). The positive and significant impact of income group implies that water-stressed, time-constrained and clustered country-level economies received more FDI, relative to their GDP, on average. This could be a result of the benefits of a developed financial system, financial institutions, reliable infrastructure, skilled labour and investment protection. More affluent countries might also have more financial and technological resources to mitigate the risks associated with water through better irrigation, reuse of wastewater, desalination, water storage and resilient city infrastructure.

UNESCO (2024) highlights the close link between water security and prosperity, capacities and sustainable economic development. Income level might therefore reflect more general structural aspects which are more important for attracting investments than the water stress alone. The year effect proved to be nonsignificant, suggesting that FDI did not consistently increase or decrease over the 2000–2022 period, when other factors are taken into account. This outcome might seem possible as financial crises, commodity cycles, geopolitical tensions, public-health emergencies, policy changes and shifts in multinational investment strategies all have an impact on global FDI flows. These disruptions can create nonlinear fluctuations which can be scarcely represented with a unique



linear time coefficient. The World Bank (2022) also mentions that the interlinkages between climate, economic and development risks are highly dynamic, depending on the time and location.

The ICC and random-intercept variance are both high, indicating that there is substantial country level heterogeneity. Despite controlling for water stress, year and income group, there were still significant differences between countries in terms of the amount of FDI. These differences could be due to unobserved factors like level of governance, exchange-rate stability, resource endowments, investment treaties, market openness, conflict exposure, environmental regulation and industrial composition. Therefore, the random-intercept model was the correct model since it allowed for the non-independence of the repeated observations in each country, and allowed for country-specific differences to not be interpreted as ordinary random variation. This study has a number of strengths: The panel is large and multinational, the study period is long (23 years), country is treated as a random effect, and two methods, REML and ML, of estimating the effects of the variables are compared. Winsorization also helped to minimize the impact of extreme values while not "losing" many of the observations. However, there were no FDI observations, no water-stress observations, some non-normality, some heteroscedasticity, and the use of an ordinal numeric predictor (income group).

Additionally, there was a lack of differentiation between water-intensive and less water-intensive investment sectors and a few limited covariates were included in the model. The nonsignificant direct effect should not be taken as an indicator from a policy perspective that water security is not a relevant factor for investment planning. It is important for governments to maintain the incorporation of water availability, water infrastructure resilience and adaptation to climate change into investment decisions as water risks could impact on specific sectors and locations, even if they do not have the same impact on total national FDI.

Investments in water security can also contribute to increased productivity, social security, and sustainable development in the long-term (World Bank, 2021). Governance, GDP growth, trade openness, inflation, infrastructure, climate hazards and the sectoral FDI should be included in future studies. Water stress-income level interactions, nonlinear time effects, and random-slope models and regional comparisons would provide more nuanced understanding of the effect of environmental pressures on investment across countries.

5. Conclusion

Longitudinal mixed-effects modelling was used to analyse the association between water stress and foreign direct investment (FDI) by country from 2000 to 2022. Results indicated that after adjusting for the effects of time and income group and clustering at the country level, the effect of water stress was slightly negative but not statistically significant for FDI. Year (calendar year) was also not significant, suggesting a non-linear trend in FDI over the study period. Income group, on the other hand, was significant and positive indicating that the higher the GDP, the more FDI as a share of GDP. These results revealed that a large amount of variation in FDI was between countries, as indicated by the intraclass correlation coefficient. This substantiates that there are country-specific effects on investments and thus justifies a random-intercept model. The similar results of the REML and ML estimates also suggested that results were consistent with the estimation method. Overall, the results indicate that water stress per se does not seem to be enough to account for the differences across countries in FDI. Investment decisions will probably be more affected by more general economic, institutional, infrastructural and policy conditions. However, water security is not a short-term issue



and is relevant to long-term economic planning, especially for water-intensive industries, and climate-vulnerable areas. Further research can be done by adding more macroeconomic and institutional variables, FDI data in sectors, comparing regions and using nonlinear or random-slope models. These extensions would enable a more complete picture of the interaction between environmental pressures and conditions of national development and the extent to which these interact to affect international investment.

References

1. Damania, R. (2020). The economics of water scarcity and variability. *Oxford Review of Economic Policy*, 36(1), 24-44.
2. Dolan, F., Lamontagne, J., Link, R., Hejazi, M., Reed, P., & Edmonds, J. (2021). Evaluating the economic impact of water scarcity in a changing world. *Nature communications*, 12(1), 1915.
3. Garrick, D. E., Hanemann, M., & Hepburn, C. (2020). Rethinking the economics of water: An assessment. *Oxford Review of Economic Policy*, 36(1), 1-23.
4. Grafton, R. Q., Chu, L., & Wyrwoll, P. (2020). The paradox of water pricing: dichotomies, dilemmas, and decisions. *Oxford Review of Economic Policy*, 36(1), 86-107.
5. He, C., Liu, Z., Wu, J., Pan, X., Fang, Z., Li, J., & Bryan, B. A. (2021). Future global urban water scarcity and potential solutions. *Nature communications*, 12(1), 4667.
6. Jones, E. R., Bierkens, M. F., & van Vliet, M. T. (2024). Current and future global water scarcity intensifies when accounting for surface water quality. *Nature Climate Change*, 14(6), 629-635.
7. Li, X., & Gallagher, K. P. (2022). Assessing the climate change exposure of foreign direct investment. *Nature Communications*, 13(1), 1451.
8. United Nations Conference on Trade and Development. (2024). *World investment report 2024: Investment facilitation and digital government*. United Nations.
9. United Nations Educational, Scientific and Cultural Organization. (2024). *The United Nations world water development report 2024: Water for prosperity and peace*. UNESCO.
10. United Nations Environment Programme. (2021). *Progress on level of water stress: Global status and acceleration needs for SDG indicator 6.4.2*. United Nations Environment Programme.
11. van Vliet, M. T. H., Jones, E. R., Flörke, M., Franssen, W. H. P., Hanasaki, N., Wada, Y., & Yearsley, J. R. (2021). Global water scarcity including surface water quality and expansions of clean water technologies. *Environmental Research Letters*, 16(2), Article 024020. <https://doi.org/10.1088/1748-9326/abbfc3>
12. World Bank. (2021). *Water security for recovery and growth*. World Bank.
13. World Bank. (2022). *Climate and development: An agenda for action*. World Bank.
14. World Bank. (2024). *World development report 2024: The middle-income trap*. World Bank.
15. World Bank. (2026a). *Foreign direct investment, net inflows (% of GDP) (BX.KLT.DINV.WD.GD.ZS)* [Data set]. World Development Indicators.
16. World Bank. (2026b). *World Bank country and lending groups* [Data set]. World Bank.
17. World Bank. (2026c). *World Development Indicators* [Data set]. World Bank.