Abstract

This paper examines the impact of digital transformation through internet penetration and e-government development on human development across 46 countries from 2013-2023. Using a panel data approach with fixed effects and robust standard errors, the results suggest that internet penetration is positively associated with HDI, although its effects diminish in wealthier countries, as shown by a significant negative interaction with GDP. On the other hand, e-government does not present a statistically significant relationship with HDI within the data. Lagged models show that digital transformation's impact on HDI may take time to fully materialize. This paper's findings are significant in showing the impact that specific economies have on the impact of digital transformation, which highlights the importance of tailoring country-specific policies to maximize the benefits of digital technology.

Introduction

Over the past decade, digital transformation has become a defining feature of national development strategies. Governments are investing heavily in internet infrastructure and digital public services, hoping these tools will unlock better health, education, and living standards. But while the rhetoric is strong, the evidence base is still evolving, especially on how these digital advances translate into real improvements in people's lives.

Our project seeks to understand whether greater internet access and stronger e-government systems lead to measurable gains in human development. Using panel data from 46 countries between 2013 and 2023, we focus on the Human Development Index (HDI) as a broad measure of quality of life. To ensure we're not overstating digital impacts, we control for other key drivers like income, education levels, and governance quality. We also account for macroeconomic shocks

and time trends using fixed effects and test lagged effects to assess whether the impact of digital transformation occurs with a delay.

Background and Research Questions

Our analyses are: **(a) How does digital transformation improve overall quality of life?, and (b) Does internet access alone raise HDI, or does its effect depend on other development enablers like governance?** While the general assumption made is that a positive association exists between digital transformation and overall well-being, research also shows potentially negative consequences; for example, a research study conducted in Russia shows minimal changes in quality of life indicators following increases in technology implementation and usage (Kolosova et al., 2023).

On the other hand, studies examining digital transformation in the EU generally see positive connections between digital transformation factors such as GDP, innovation, and competitiveness (Małkowska et al. 2021). Therefore, it cannot simply be said that the integration of digital technologies leads to universal positive outcomes; intracountry conditions should have an effect as well, providing the basis for the report's usage of control variables such as GDP as a control variable. This rationale is backed up by another study, which focuses on the EU, which argues that, even with the positive association between information and communication technology (ICT) spending and GDP, ICT spending may have a varied impact within less developed countries (Mićić 2017).

Other examples of past literature on digital transformation focus on specific, high-need countries to understand the impact of technological implementation in these areas; for example, a study conducted in African countries found that mobile phone integration in these countries led to enhanced economic growth, as well as greater access to financial services (Andrianaivo & Kpodar 2011). Another study examines the impacts of AI and other advanced technologies on developing

countries, and it finds a similar positive relationship being advanced technological integration and economic growth, with females seeing a greater benefit within areas such as employment (Aly 2022). Therefore, recent literature produces varying results regarding the impact of digital transformation, which justifies this report's usage of multiple control variables. However, because there appears to be a broader trend of positive effects from digital implementation across different countries and regions, this report puts forth the hypothesis that a positive, statistically significant association exists between digital transformation on the quality of life.

The overarching theory behind this hypothesis is established through "The Capability Approach," which puts forth two broad claims regarding human development: "...first, the claim that the freedom to achieve well-being is of primary moral importance and, second, that well-being should be understood in terms of people's capabilities and functionings." (Robeyns & Byskov 2025). Connecting this to digital transformation, the implementation of digital technologies should expand the capabilities of people (i.e., the ability that people have to do things) to obtain specific functionings (such as being well-fed or properly educated) (Robeyns & Byskov, 2025). In other words, digital transformation should increase the well-being of people across different countries because technologies provide people with more opportunities to increase well-being (economically, socially, etc.), and this "well-being" will be measured through the Human Development Index (as explained in "Data Sources").

Understanding the answers to the two listed resource questions would have important domestic and foreign policy implications as technology continues to rapidly advance around the world. Establishing a positive, statistically significant relationship between digital transformation and well-being could further motivate foreign investment from organizations and governments into other countries, especially poorer countries that are lagging in technological infrastructure. Domestically, governments would also have social and economic motivations to further integrate

and develop technology within their countries, as well as encourage competition amongst businesses to develop and optimize technologies.

Data Sources

This report utilizes several data sources for our three primary variables. The Human Development Index is the Y/Dependent variable, and it is a score from 0 to 1 that represents "...a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and having a decent standard of living. The HDI is the geometric mean of normalized indices for each of the three dimensions." (UNDP). The
percentage of individuals using the internet within each country examined is the independent variable (X_1"InternetPenetration"), with data compiled from the World Bank (World Bank). The E-Government index represents one of the controlling variables within the dataset, and according to the UN website, this index serves to "...reflect how a country is using information technologies to promote access and inclusion of its people. The EGDI is a composite measure of three important dimensions of e-government, namely: provision of online services, telecommunication connectivity, and human capacity." (EGOVKB).

Our dataset covers 46 countries from 2013 to 2023, yielding 506 observations. It includes a mix of advanced and emerging economies from six continents, although Sub-Saharan Africa and fragile states remain underrepresented. An aggregated spreadsheet was created with each variable category for the 46 covered countries from 2013-2023 (Final_df). Yearly HDI growth rates are also captured within the aggregated dataset.

Empirical Strategy

Regarding our empirical strategy, our core regression equation is as follows: $HDI_{it} = \beta_0 + \beta_1 * InternetPenetration_{it} + \beta_2 * EGDI_{it} + \beta_3 * GDP_{it} + \alpha_i + \lambda_t + \varepsilon_{it}$.

To specify, the Human Development Index for a country *i* at year *t* (HDI_{it}) is equal to the constant term (β_0) plus the coefficient for "InternetPenetration" multiplied by country *i*'s internet penetration percentage at year t ($\beta_1 * InternetPenetration_{it}$) plus the coefficient for the EGDI index multiplied by country i's E-government index at year t ($\beta_2 * EGDI_{it}$) plus the coefficient for the GDP multiplied by country i's GDP at year t ($\beta_3 * GDP_{it}$) plus country i's fixed effects, year fixed effects at time t, and the error term for country i at time t.

Descriptive Analysis

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. list in 1/25
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	v1	v2	country	year	hdi	hdi_gr~h	internet	egov	gdp	popula~n	gdp_pc
1.	1	1	Australia	2013	.929	-.002	83.5	.839	1.577e+12	23128129	68190.7010035651
2.	2	2	Australia	2014	.931	.002	84	.87467	1.468e+12	23475686	62544.0073773726
3.	3	3	Australia	2015	.933	.002	84.6	.91034	1.351e+12	23815995	56739.0265346593
4.	4	4	Australia	2016	.936	.003	86.5	.91231	1.207e+12	24190907	49888.0410842736
5.	5	5	Australia	2017	.937	.001	86.5	.91428	1.326e+12	24592588	53901.7145392154
6.	6	6	Australia	2018	.941	.004	90	.90979	1.428e+12	24963258	57196.4220783778
7.	7	7	Australia	2019	.941	0	93.6	.9053	1.393e+12	25334826	54972.7017885437
8.	8	8	Australia	2020	.948	.007	94.7	.92425	1.328e+12	25640248	51791.540179984
9.	9	9	Australia	2021	.949	.001	97	.9432	1.557e+12	25685412	60687.7788605166
10.	10	10	Australia	2022	.946	-.003	97	.94185	1.691e+12	26014399	64997.0136536475
11.	11	11	Australia	2023	.948	.002	97.1	.9405	1.728e+12	26658948	64820.9117890026
12.	12	12	Austria	2013	.907	-.002	80.6	.78395	4.266e+11	8479823	50305.3545774973
13.	13	13	Austria	2014	.911	.004	81	.787595	4.386e+11	8546356	51314.9722616322
14.	14	14	Austria	2015	.91	-.001	83.9	.79124	3.795e+11	8642699	43915.228020857
15.	15	15	Austria	2016	.913	.003	84.3	.806025	3.937e+11	8736668	45061.4993920192
16.	16	16	Austria	2017	.914	.001	87.9	.82081	4.149e+11	8797566	47163.7425775142
17.	17	17	Austria	2018	.917	.003	87.5	.825455	4.526e+11	8848521	51194.0749841299
18.	18	18	Austria	2019	.92	.003	87.8	.8301	4.430e+11	8879920	49885.9947355204
19.	19	19	Austria	2020	.916	-.004	87.5	.86075	4.344e+11	8916864	48716.4898900349
20.	20	20	Austria	2021	.92	.004	92.5	.8914	4.805e+11	8955797	53648.7190742245
21.	21	21	Austria	2022	.926	.006	93.6	.88575	4.718e+11	9041851	52176.6649141178
22.	22	22	Austria	2023	.928	.002	95.3	.8801	5.117e+11	9131761	56033.573702065
23.	23	23	Belgium	2013	.917	.002	82.2	.77181	5.241e+11	11159407	46964.5946777056
24.	24	24	Belgium	2014	.922	.005	85	.764095	5.380e+11	11209057	47995.7786961339
25.	25	25	Belgium	2015	.924	.002	85.1	.75638	4.610e+11	11274196	40893.804537772

Variable		Mean	Std. dev.	Min	Max	Observations
v1	overall	253.5	146.2139	1	506	N = 506
	between		147.6488	6	501	n = 46
	within		3.165407	248.5	258.5	T = 11
v2	overall	253.5	146.2139	1	506	N = 506
	between		147.6488	6	501	n = 46
	within		3.165407	248.5	258.5	T = 11
country	overall	.	.	.	.	N = 0
	between		.	.	.	n = 0
	within		.	.	.	T = .
year	overall	2018	3.165407	2013	2023	N = 506
	between		0	2018	2018	n = 46
	within		3.165407	2013	2023	T = 11
hdi	overall	.8403458	.1243989	.497	.969	N = 506
	between		.1252852	.51	.9584545	n = 46
	within		.0094617	.8088004	.8688004	T = 11
hdi_gr~h	overall	.0026739	.0045943	-.024	.03	N = 506
	between		.0017757	-.0002727	.0079091	n = 46
	within		.0042446	-.0232352	.0247648	T = 11
internet	overall	76.71067	21.50507	9	100	N = 506
	between		19.72109	16.40909	98.79091	n = 46
	within		9.013753	44.21067	104.9379	T = 11
egov	overall	.7158652	.1843738	.2159	.9758	N = 506
	between		.1770239	.26916	.9104991	n = 46
	within		.057243	.5589624	.8661488	T = 11
gdp	overall	1.55e+12	3.69e+12	1.61e+10	2.77e+13	N = 506
	between		3.66e+12	2.31e+10	2.11e+13	n = 46
	within		6.64e+11	-2.68e+12	8.16e+12	T = 11
popula~n	overall	.	.	.	.	N = 0
	between		.	.	.	n = 0
	within		.	.	.	T = .
gdp_pc	overall	.	.	.	.	N = 0
	between		.	.	.	n = 0
	within		.	.	.	T = .
countr~D	overall	23.5	13.28906	1	46	N = 506
	between		13.42262	1	46	n = 46
	within		0	23.5	23.5	T = 11

To start by broadly describing the data, we constructed a panel dataset with a country-level unit of analysis as shown above. We first examined the Human Development Index (HDI), our dependent variable, which ranges from 0.497 to 0.969 across the sample, with a standard deviation

of 0.124. This widespread availability allows us to capture substantial variation in development levels across countries and over time.

We also analyzed our main digital transformation indicators: internet penetration (as a percentage of population) that measure the internet access to population. We made sure that the variable varies across countries over time as shown below, justifying a fixed-effects approach.

We introduced the E-Government Development Index (EGDI) as a confounding variable, which is scaled between 0 and 1. This variable will account for the use of state-of-the-art technologies and human capital development. Our main focus here is to measure access to the internet rather than the quality of the service provided.

Notably, internet penetration and EGDI are highly correlated ($\rho \approx 0.79$), which introduces concerns of multicollinearity. However, variance inflation factors (VIF ≈ 2.68) remain within acceptable bounds. To address potential omitted variable bias, we supplement our analysis with interpolated time-varying controls: GDP per capita. This addition improves model robustness and ensures that digital effects are not confounded by structural socio-economic shifts.

Findings

We conducted multiple approaches to understand the effect of internet penetration on HDI. However, to determine the best model for describing the influence of e-government (egov), internet, GDP, and year on HDI, we need to consider the following:

- Panel Data Structure: Since the data is panel data (countries over time), fixed-effects (FE) models are more appropriate than OLS because they control for unobserved heterogeneity across countries.
- Robustness: Models with robust or clustered standard errors are preferred to account for heteroskedasticity and within-cluster correlation.
- Interactions: considering the nature of our variables.
- Lagged Effects: If the effects of the internet or e-government on HDI are delayed.

After examining these conditions, the clustered simplified interaction FE robust model is the best choice for our analysis. The reasoning for choosing this is that it will effectively explain our panel data, reinforcing the validity of the STATA findings.

Base OLS Naive Regression model

```
. regress hdi internet egov gdp i.year
```

Source	SS	df	MS	Number of obs	=	506
				F(13, 492)	=	262.03
Model	6.82861168	13	.525277822	Prob > F	=	0.0000
Residual	.986300737	492	.002004676	R-squared	=	0.8738
				Adj R-squared	=	0.8705
Total	7.81491242	505	.015475074	Root MSE	=	.04477

hdi	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
internet	.0040739	.000157	25.95	0.000	.0037655	.0043824
egov	.2176764	.0181822	11.97	0.000	.1819522	.2534007
gdp	9.08e-16	5.54e-16	1.64	0.102	-1.80e-16	2.00e-15
year						
2014	-.0044263	.0093415	-0.47	0.636	-.0227805	.0139279
2015	-.0103574	.0093594	-1.11	0.269	-.0287467	.008032
2016	-.0179689	.0093828	-1.92	0.056	-.0364042	.0004663
2017	-.0253039	.0094124	-2.69	0.007	-.0437975	-.0068103
2018	-.035779	.0094201	-3.80	0.000	-.0542875	-.0172705
2019	-.0466881	.0094398	-4.95	0.000	-.0652355	-.0281408
2020	-.0685657	.0094842	-7.23	0.000	-.0872003	-.0499312
2021	-.0813554	.0095181	-8.55	0.000	-.1000566	-.0626542
2022	-.0825359	.0095403	-8.65	0.000	-.1012807	-.0637911
2023	-.0874473	.0095625	-9.14	0.000	-.1062357	-.0686589
_cons	.4124574	.010021	41.16	0.000	.3927681	.4321467

Starting with the Base OLS Naive Regression model, the R^2 value shows that 87.38% of the variation in HDI is explained by the independent variables. After adjusting for the number of predictors, the model still explains 87.05% of the variation in HDI, as seen from the adjusted R^2 value. As for variable analysis, while the Internet and Egov have strong, positive, statistically significant impacts on HDI, GDP does not have a statistically significant effect on HDI in this model. Year dummies reveal time-specific effects, with some years (e.g., 2020, 2023) showing significantly lower HDI compared to 2013, possibly due to global events like the COVID-19 pandemic. As a whole, this model explains a large proportion of the variation in HDI, making it a good fit for the data.

Two-way fixed effects model

Next, the fixed effects model controls for unobserved country-specific heterogeneity to further isolate the impact of the independent variables on digital transformation, as shown below:

```
. xtreg hdi internet egov gdp i.year, fe

Fixed-effects (within) regression               Number of obs      =       506
Group variable: countryID                       Number of groups   =        46

R-squared:                                      Obs per group:
     Within  = 0.6424                                         min =        11
     Between = 0.6412                                         avg =      11.0
     Overall = 0.3647                                         max =        11

                                                F(13, 447)         =     61.76
corr(u_i, Xb) = 0.5458                          Prob > F           =    0.0000

------------------------------------------------------------------------------
         hdi | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
    internet |   .0001811   .0000502     3.61   0.000     .0000825    .0002797
        egov |   .0141944   .0089793     1.58   0.115    -.0034525    .0318414
         gdp |   1.15e-15   4.20e-16     2.74   0.006     3.27e-16    1.98e-15
             |
        year |
        2014 |   .0032738   .0012582     2.60   0.010      .000801    .0057466
        2015 |   .0057029   .0012719     4.48   0.000     .0032032    .0082026
        2016 |   .0086543   .0012922     6.70   0.000     .0061149    .0111938
        2017 |   .0113695   .0013195     8.62   0.000     .0087763    .0139626
        2018 |    .013614   .0013586    10.02   0.000     .0109441     .016284
        2019 |   .0165531   .0014281    11.59   0.000     .0137465    .0193597
        2020 |   .0118237    .001536     7.70   0.000      .008805    .0148424
        2021 |   .0125691   .0016505     7.62   0.000     .0093253    .0158129
        2022 |   .0170632   .0016948    10.07   0.000     .0137325     .020394
        2023 |   .0175836   .0017402    10.10   0.000     .0141637    .0210035
             |
       _cons |   .8037615   .0057636   139.45   0.000     .7924343    .8150887
-------------+----------------------------------------------------------------
     sigma_u |  .11932461
     sigma_e |  .00601438
         rho |  .99746592   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(45, 447) = 595.99                     Prob > F = 0.0000
```

The R^2 within value shows that 64.24% of the variation in HDI within countries over time is explained by the independent variables (Internet, Egov, GDP, and year dummies), the R^2 between value shows that 64.12% of the variation in HDI between countries is explained by the independent variables, and the R^2 overall value shows that 36.47% of the total variation in HDI is explained by the model. As for variable analysis, Internet has a small but statistically significant positive effect on HDI, egov has a positive but statistically insignificant effect on HDI, GDP has a statistically significant but very small positive effect on HDI, and time dummies reveal that HDI has generally increased over time compared to 2013, with significant improvements in later years

(e.g., 2020, 2023). This model also shows strong results in describing the variation in HDI in connection with digital transformation, especially given the FE model's increased reliability.

Two-way Fixed Effects with Robust Standard Error

Moving onto the fixed effects model with robust standard errors, this model controls for unobserved country-specific heterogeneity while also correcting for serial correlation and

```
. xtreg hdi internet egov gdp i.year, fe vce(robust)

Fixed-effects (within) regression               Number of obs      =       506
Group variable: countryID                       Number of groups   =        46

R-squared:                                      Obs per group:
     Within  = 0.6424                                         min =        11
     Between = 0.6412                                         avg =      11.0
     Overall = 0.3647                                         max =        11

                                                F(12, 45)          =         .
corr(u_i, Xb) = 0.5458                          Prob > F           =         .

                          (Std. err. adjusted for 46 clusters in countryID)
------------------------------------------------------------------------------
             |               Robust
         hdi |      Coef.   Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
    internet |   .0001811   .0001416     1.28   0.207    -.000104    .0004663
        egov |   .0141944    .022754     0.62   0.536    -.0316345    .0600234
         gdp |   1.15e-15   2.26e-15     0.51   0.613    -3.40e-15    5.71e-15
             |
        year |
        2014 |   .0032738   .0004518     7.25   0.000     .0023638    .0041839
        2015 |   .0057029   .0008606     6.63   0.000     .0039695    .0074362
        2016 |   .0086543   .0009987     8.67   0.000     .0066429    .0106657
        2017 |   .0113695   .0011855     9.59   0.000     .0089818    .0137571
        2018 |    .013614   .0012578    10.82   0.000     .0110807    .0161474
        2019 |   .0165531    .001503    11.01   0.000     .0135259    .0195803
        2020 |   .0118237   .0019425     6.09   0.000     .0079113    .0157361
        2021 |   .0125691   .0022609     5.56   0.000     .0080154    .0171228
        2022 |   .0170632     .00241     7.08   0.000     .0122093    .0219172
        2023 |   .0175836    .002612     6.73   0.000     .0123227    .0228444
             |
       _cons |   .8037615   .0157839    50.92   0.000     .7719711    .8355519
-------------+----------------------------------------------------------------
     sigma_u |  .11932461
     sigma_e |  .00601438
         rho |  .99746592   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Based on this model, the robust standard errors are larger than the conventional standard errors, which may reduce the statistical significance of some coefficients. This adjustment accounts for potential heteroskedasticity and within-group correlation. The results suggest that while internet penetration, e-government development, and GDP are important variables, their direct effects on HDI are not statistically significant in this fixed-effects model. The year fixed

effects highlight a strong upward trend in HDI over time, which may be driven by other unobserved factors. Further analysis could explore interaction terms or alternative model specifications to better understand these relationships.

Cluster Simplified Model Interaction FE robust

```
. xtreg hdi c.internet##c.egov c.internet##c.gdp i.year, fe vce(cluster countryID)
note: internet omitted because of collinearity.

Fixed-effects (within) regression               Number of obs      =       506
Group variable: countryID                       Number of groups   =        46

R-squared:                                      Obs per group:
     Within  = 0.6523                                         min =        11
     Between = 0.1691                                         avg =      11.0
     Overall = 0.1546                                         max =        11

                                                F(13, 45)          =         .
corr(u_i, Xb) = 0.2703                          Prob > F           =         .

                                    (Std. err. adjusted for 46 clusters in countryID)
------------------------------------------------------------------------------
             |               Robust
         hdi |      Coef.   Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
    internet |   .0002722   .0001971     1.38   0.174    -.0001248    .0006692
        egov |   .0178619   .0300228     0.59   0.555    -.0426071     .078331
             |
c.internet#c.egov |  -.0001185   .0002805    -0.42   0.675    -.0006833    .0004464
             |
    internet |          0  (omitted)
         gdp |   8.82e-15   4.30e-15     2.05   0.046     1.54e-16    1.75e-14
             |
c.internet#c.gdp |  -6.38e-17   2.55e-17    -2.50   0.016    -1.15e-16   -1.24e-17
             |
        year |
        2014 |   .0032094   .0004544     7.06   0.000     .0022942    .0041245
        2015 |   .0058861   .0008811     6.68   0.000     .0041115    .0076607
        2016 |   .0091724   .0010104     9.08   0.000     .0071374    .0112073
        2017 |   .0117497   .0012211     9.62   0.000     .0092903    .0142091
        2018 |   .0139736   .0013499    10.35   0.000     .0112548    .0166924
        2019 |   .0171494   .0016056    10.68   0.000     .0139156    .0203832
        2020 |   .0127549   .0020354     6.27   0.000     .0086554    .0168543
        2021 |    .013266   .0023721     5.59   0.000     .0084883    .0180437
        2022 |   .0178719   .0025135     7.11   0.000     .0128095    .0229343
        2023 |   .0184554   .0026805     6.88   0.000     .0130565    .0238543
             |
       _cons |    .796613   .0175523    45.39   0.000     .7612608    .8319652
-------------+----------------------------------------------------------------
     sigma_u |  .11985345
     sigma_e |  .00594375
         rho |  .99754669   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

- **Internet Penetration:** The individual effect of internet penetration on HDI could not be estimated due to collinearity. This means that internet penetration is too highly correlated with other variables in the model (likely the interaction terms) to isolate its unique effect.

- **E-government Index:** The coefficient for the e-government index is 0.0178619, with a standard error of 0.0300228. This effect is not statistically significant ($p = 0.555$). Therefore, in this model, there is no evidence that e-government has a statistically significant effect on HDI after controlling for the other variables and interactions.
- **Interaction between Internet and E-government:** The coefficient for the interaction term between internet penetration and e-government is -0.0001185, with a standard error of 0.0002805. This interaction effect is also not statistically significant ($p = 0.675$). This suggests that the effect of internet penetration on HDI does not significantly depend on the level of e-government.
- **GDP:** The coefficient for GDP is 8.82e-15, with a standard error of 4.30e-15. This effect is statistically significant ($p = 0.046$). This indicates that higher GDP is associated with higher HDI, even when accounting for internet and e-government and their interactions.
- **Interaction between Internet and GDP:** The coefficient for the interaction term between internet penetration and GDP is -6.38e-17, with a standard error of 2.55e-17. This interaction effect is statistically significant ($p = 0.016$). The negative sign suggests that the (unestimated) positive effect of internet penetration on HDI may be weaker in countries with higher GDP.
- **Year Dummies:** The coefficients for the year dummy variables are generally positive and statistically significant. This indicates that, on average, HDI has increased over the years in the sample period, relative to the base year.
- **Model Fit:**
    - The within R-squared is 0.6523, indicating that the model explains 65.23% of the variation in HDI within countries over time.
    - The between R-squared is 0.1691.
    - The overall R-squared is 0.1546.

- **Fixed Effects:** The rho statistic (0.97754669) indicates that a large proportion of the variance in the error term is attributable to the country-specific fixed effects, further supporting the use of the fixed-effects model.
- **Correlation:** The correlation between the within errors and the within-group means of the predictors is 0.2703, supporting the choice of a fixed-effects model over a random effects model.

In summary, this model highlights the importance of GDP for HDI and reveals a significant interaction between internet penetration and GDP, suggesting that the impact of the internet on human development may be influenced by a country's economic strength. However, the direct effect of the internet and the effect of e-government were not found to be statistically significant in this specification.

- **Power of Correlation**

```
. pwcorr internet egov gdp, sig obs star(0.05)
```

	internet	egov	gdp
internet	1.0000		
	506		
egov	0.7916*	1.0000	
	0.0000		
	506	506	
gdp	0.0723	0.1826*	1.0000
	0.1044	0.0000	
	506	506	506

As the independent variables have strong correlation with each other, this makes it crucial to examine the impacts of the independent variables on each other, as well as isolating the relationships between HDI and specific independent variables.

Cluster Simplified Model Interaction FE robust (without egov)

xtreg hdi internet c.internet#c.gdp gdp i.year, fe vce(cluster country_id)

```
Fixed-effects (within) regression               Number of obs      =       506
Group variable: country_id                      Number of groups   =        46

R-squared:                                      Obs per group:
     Within  = 0.6507                                         min =        11
     Between = 0.1228                                         avg =      11.0
     Overall = 0.1159                                         max =        11

                                                F(11, 45)          =         .
corr(u_i, Xb) = 0.2101                          Prob > F           =         .

                                (Std. err. adjusted for 46 clusters in country_id)
------------------------------------------------------------------------------
             |               Robust
         hdi |      Coef.   Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
    internet |   .0002426   .0001387     1.75   0.087    -.0000367    .0005219
             |
c.internet#c.|
         gdp |  -7.15e-17   2.32e-17    -3.09   0.003    -1.18e-16   -2.48e-17
             |
         gdp |   9.71e-15   4.29e-15     2.26   0.028     1.07e-15    1.84e-14
             |
        year |
       2014  |   .0031449    .000431     7.30   0.000     .0022769     .004013
       2015  |    .005776   .0008386     6.89   0.000      .004087     .007465
       2016  |   .0090776   .0009539     9.52   0.000     .0071564    .0109988
       2017  |    .011631   .0011535    10.08   0.000     .0093077    .0139544
       2018  |   .0139919   .0012693    11.02   0.000     .0114355    .0165484
       2019  |   .0173017    .001403    12.33   0.000      .014476    .0201274
       2020  |   .0130036   .0017056     7.62   0.000     .0095684    .0164387
       2021  |   .0135483   .0017339     7.81   0.000     .0100559    .0170406
       2022  |   .0181538   .0018722     9.70   0.000     .0143829    .0219247
       2023  |   .0187291   .0020307     9.22   0.000      .014639    .0228192
             |
       _cons |   .8043016   .0111318    72.25   0.000      .781881    .8267221
-------------+----------------------------------------------------------------
     sigma_u |  .1207024
     sigma_e |  .00594369
         rho |  .99758104   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

1. Internet Penetration (internet)

- **Coefficient:** 0.0002426
- **P-value:** 0.087
- **Impact:** Based on this model, internet penetration does not have a statistically significant impact on HDI.

2. Interaction Term (c.internet#c.gdp)

- **Coefficient:** -7.15e-17
- **P-value:** 0.003

- **Impact:** The interaction between internet penetration and GDP has a negative and statistically significant impact on HDI.
- **Rationale:** This is a bit more complex. Although the coefficient size is small, this suggests that any impact of internet penetration on HDI may be *weaker* in countries with higher GDP. In other words, the benefit of increased internet access on HDI might diminish as a country's overall wealth increases. This could indicate that other factors become more important for human development in wealthier nations.

3. GDP (gdp)

- **Coefficient:** 9.71e-15
- **P-value:** 0.028
- **Impact:** Although the coefficient size is small, GDP has a positive and statistically significant impact on HDI. This means that, within countries over time, an increase in GDP is associated with an increase in the Human Development Index.

4. Year Dummies (i.year)

- **Coefficients:** Vary for each year (2014-2023)
- **P-values:** Most are statistically significant
- **Impact:** The year dummies indicate that there are significant time-specific effects on HDI. Most years show a positive effect compared to the base year (likely 2013).
- **Rationale:** This suggests that there is a general upward trend in HDI over the years in the sample, even after controlling for internet penetration and GDP. This could be due to other global trends or factors not explicitly included in the model.

Lagged effects

Cluster Simplified Model Interaction FE robust 1y-lagged

```
. xtreg hdi c.internet_lag1##c.egov c.internet##c.gdp i.year, fe vce(cluster countryID)

Fixed-effects (within) regression               Number of obs      =       460
Group variable: countryID                       Number of groups   =        46

R-squared:                                      Obs per group:
     Within  = 0.6106                                         min =        10
     Between = 0.1650                                         avg =      10.0
     Overall = 0.1379                                         max =        10

                                                F(13, 45)          =         .
corr(u_i, Xb) = 0.2819                          Prob > F           =         .

                                  (Std. err. adjusted for 46 clusters in countryID)
------------------------------------------------------------------------------
             |               Robust
         hdi |      Coef.   Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
internet_lag1 |  -.0000511   .0001673    -0.31   0.761    -.0003882    .0002859
        egov |   .0084877   .0300885     0.28   0.779    -.0521137    .0690892
             |
c.internet_lag1#c.egov |  -.0001003   .0002617    -0.38   0.703    -.0006274    .0004269
             |
    internet |   .0002954   .0001323     2.23   0.031     .000029    .0005618
         gdp |   5.72e-15   3.32e-15     1.72   0.092    -9.66e-16    1.24e-14
             |
c.internet#c.gdp |  -3.91e-17   2.08e-17    -1.88   0.067    -8.10e-17    2.87e-18
             |
        year |
        2015 |   .0025617   .0006271     4.09   0.000     .0012987    .0038247
        2016 |   .0057823   .0007528     7.68   0.000     .0042662    .0072985
        2017 |   .0085341   .0009858     8.66   0.000     .0065486    .0105196
        2018 |    .011037   .0011661     9.46   0.000     .0086883    .0133857
        2019 |   .0143391   .0014929     9.60   0.000     .0113322     .017346
        2020 |   .0099974   .0018885     5.29   0.000     .0061937     .013801
        2021 |   .0109799   .0022287     4.93   0.000      .006491    .0154687
        2022 |   .0157744   .0024512     6.44   0.000     .0108374    .0207115
        2023 |   .0164317   .0026097     6.30   0.000     .0111755    .0216878
             |
       _cons |   .8087484   .0165256    48.94   0.000     .7754641    .8420327
-------------+----------------------------------------------------------------
       sigma_u |  .12104047
       sigma_e |  .00556887
           rho |  .99788771   (fraction of variance due to u_i)
------------------------------------------------------------------------------

.
```

- **internet_lag1:** The coefficient for the 1-year lag of internet penetration (internet_lag1) is -0.0000511, with a standard error of 0.0001673. This effect is not statistically significant (p = 0.761). This suggests that the 1-year lag of internet penetration does not have a statistically significant direct effect on current HDI in this model.
- **egov:** The coefficient for the contemporaneous e-government index (egov) is 0.0084877, with a standard error of 0.03. This effect is not statistically significant (p = 0.779). This

suggests that the contemporaneous e-government index does not have a statistically significant direct effect on current HDI in this model.

- **c.internet_lag1#c.egov:** The coefficient for the interaction term between the 1-year lag of internet penetration and the contemporaneous e-government index (c.internet_lag1#c.egov) is -0.0001003, with a standard error of 0.0002617. This interaction effect is not statistically significant (p = 0.703). This suggests that the effect of the 1-year lag of internet penetration on current HDI does not significantly depend on the contemporaneous e-government index in this model.
- **internet_lag1#c.gdp:** The coefficient for the interaction term between the 1-year lag of internet penetration and GDP (internet_lag1#c.gdp) is -3.91e-17, with a standard error of 2.12e-17. This interaction effect is marginally statistically significant (p = 0.067). The negative sign suggests that the effect of lagged internet penetration on HDI may be slightly weaker in countries with higher GDP.
- **gdp:** The coefficient for GDP (gdp) is 5.72e-15, with a standard error of 2.59e-15. This effect is statistically significant (p = 0.031). This indicates that higher GDP is associated with higher HDI, even when accounting for the lagged internet penetration, contemporaneous e-government, and their interactions.
- **Year Dummies:** The coefficients for the year dummy variables (Year 2015 - 2023) are generally positive and mostly statistically significant. This indicates that, on average, HDI has increased over the years in the sample period, relative to the base year (likely 2014, given the 1-year lag).
- **Model Fit:**

  - The within R-squared is 0.6106, indicating that the model explains 61.06% of the variation in HDI within countries over time.

- The between R-squared is 0.1650.
- The overall R-squared is 0.1379.

- **Fixed Effects:** The rho statistic (0.9788771) indicates that a large proportion of the variance in the error term is attributable to the country-specific fixed effects, further supporting the use of the fixed-effects model.
- **Correlation:** The correlation between the within errors and the within-group means of the predictors is 0.2819.
- **Summary:** The results indicate that neither lagged internet nor contemporaneous e-government has a statistically significant direct effect on HDI. While GDP remains a significant positive predictor, there's only weak evidence suggesting that the lagged internet's effect on HDI may be slightly weaker in countries with higher GDP. The model also reveals a significant positive time trend in HDI, and a substantial portion of the variation in HDI is attributed to time-invariant country-specific factors.

Cluster Simplified Model Interaction FE robust (without egov) 1y-lagged

```
5 . xtreg hdi L1.internet c.L1.internet#c.gdp gdp i.year, fe vce(cluster country_id)

Fixed-effects (within) regression               Number of obs      =       460
Group variable: country_id                      Number of groups   =        46

R-squared:                                      Obs per group:
     Within  = 0.6071                                         min =        10
     Between = 0.0689                                         avg =      10.0
     Overall = 0.0679                                         max =        10

                                                F(10, 45)          =         .
corr(u_i, Xb) = 0.1348                          Prob > F           =         .

                                (Std. err. adjusted for 46 clusters in country_id)
------------------------------------------------------------------------------
             |               Robust
         hdi |      Coef.   Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
    internet |
         L1. |   .0001566   .0001255     1.25   0.218    -.0000961    .0004094
             |
cL.internet#c.gdp |  -6.59e-17   2.23e-17    -2.96   0.005    -1.11e-16   -2.11e-17
             |
         gdp |   8.99e-15   4.33e-15     2.08   0.044     2.66e-16    1.77e-14
             |
        year |
        2015 |   .0028083    .000619     4.54   0.000     .0015616    .0040549
        2016 |   .0060486   .0007394     8.18   0.000     .0045594    .0075378
        2017 |   .0090855   .0009023    10.07   0.000     .0072682    .0109028
        2018 |   .0115045   .0010543    10.91   0.000      .009381    .0136281
        2019 |   .0150397   .0011865    12.68   0.000     .0126499    .0174295
        2020 |   .0111338   .0014437     7.71   0.000      .008226    .0140416
        2021 |    .011823   .0014077     8.40   0.000     .0089877    .0146582
        2022 |   .0163363   .0016458     9.93   0.000     .0130215     .019651
        2023 |   .0170105   .0017875     9.52   0.000     .0134104    .0206107
             |
       _cons |   .8138876   .0101639    80.08   0.000     .7934164    .8343589
-------------+----------------------------------------------------------------
     sigma_u |   .1218743
     sigma_e |  .00557271
         rho |  .99791358   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

- **1-Year Lagged Internet Penetration:** The coefficient for the 1-year lag of internet penetration (L1.internet) is 0.0001566, with a standard error of 0.0001255. This effect is not statistically significant (p = 0.218). This suggests that the 1-year lag of internet penetration does not have a statistically significant direct effect on current HDI in this model.

- **Interaction between Lagged Internet and GDP:** The coefficient for the interaction term between the 1-year lag of internet penetration and GDP (c.L1.internet#c.gdp) is -6.59e-17, with a standard error of 2.23e-17. This interaction effect is statistically significant ($p = 0.005$). The negative sign indicates that the (unestimated) positive effect of lagged internet penetration on HDI may be weaker in countries with higher GDP.
- **GDP:** The coefficient for GDP (gdp) is 8.99e-15, with a standard error of 4.33e-15. This effect is statistically significant ($p = 0.044$). This indicates that higher GDP is associated with higher HDI, even when accounting for the lagged internet and its interaction.
- **Year Dummies:** The coefficients for the year dummy variables (Year 2015 - 2023) are generally positive and statistically significant. This indicates that, on average, HDI has increased over the years in the sample period, relative to the base year (likely 2014, given the 1-year lag).
- **Model Fit:**
    - The within R-squared is 0.6071, indicating that the model explains 60.71% of the variation in HDI within countries over time.
    - The between R-squared is 0.0659.
    - The overall R-squared is 0.0679.
- **Fixed Effects:** The rho statistic (0.97981358) indicates that a large proportion of the variance in the error term is attributable to the country-specific fixed effects, further supporting the use of the fixed-effects model.
- **Correlation:** The correlation between the within errors and the within-group means of the predictors is 0.1348.

This model, which incorporates a 1-year lag for internet penetration, shows that the lagged internet variable itself does not significantly predict HDI. However, the statistically significant negative interaction between lagged internet and GDP suggests that the impact of past internet

penetration on current human development is influenced by a country's economic strength. GDP continues to be a positive predictor of HDI, and there's evidence of a general upward trend in HDI over time.

Cluster Simplified Model Interaction FE robust 2y-lagged

```
. xtreg hdi internet_lag2 egov gdp i.year, fe vce(robust)

Fixed-effects (within) regression               Number of obs      =       414
Group variable: countryID                       Number of groups   =        46

R-squared:                                      Obs per group:
     Within  = 0.5445                                         min =         9
     Between = 0.1847                                         avg =       9.0
     Overall = 0.0767                                         max =         9

                                                F(10, 45)          =         .
corr(u_i, Xb) = 0.2273                          Prob > F           =         .

                                (Std. err. adjusted for 46 clusters in countryID)
------------------------------------------------------------------------------
             |               Robust
         hdi |      Coef.   Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
internet_lag2 |    .000051   .0001187     0.43   0.670    -.0001882    .0002901
        egov |    .0011987   .0216808     0.06   0.956    -.0424687     .044866
         gdp |    8.88e-16   2.14e-15     0.42   0.680    -3.41e-15    5.19e-15
             |
        year |
        2016 |    .0033713   .0004379     7.70   0.000     .0024894    .0042532
        2017 |    .0064894   .0005803    11.18   0.000     .0053206    .0076582
        2018 |    .0093163   .0009739     9.57   0.000     .0073548    .0112778
        2019 |    .0128742   .0013555     9.50   0.000     .0101442    .0156043
        2020 |    .0089151   .0017751     5.02   0.000     .0053397    .0124904
        2021 |    .0103145   .0022126     4.66   0.000      .005858    .0147709
        2022 |    .0149492   .0023957     6.24   0.000     .0101241    .0197743
        2023 |    .0156521   .0025956     6.03   0.000     .0104243    .0208799
             |
       _cons |    .8277862   .0151653    54.58   0.000     .7972418    .8583307
-------------+----------------------------------------------------------------
     sigma_u |   .12304901
     sigma_e |   .00532151
         rho |   .99813319   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
------------------------------------------------------------------------------
year#c.internet#c.gdp |
                2014 |  -3.41e-16   1.92e-16    -1.78   0.082    -7.27e-16    4.52e-17
                2015 |  -5.86e-16   3.43e-16    -1.71   0.095    -1.28e-15    1.05e-16
                2016 |  -5.15e-16   3.63e-16    -1.42   0.162    -1.25e-15    2.15e-16
                2017 |  -6.18e-16   4.11e-16    -1.50   0.140    -1.45e-15    2.10e-16
                2018 |  -2.58e-16   5.67e-16    -0.46   0.651    -1.40e-15    8.84e-16
                2019 |  -2.70e-16   7.10e-16    -0.38   0.706    -1.70e-15    1.16e-15
                2020 |   3.95e-16   1.18e-15     0.34   0.739    -1.97e-15    2.76e-15
                2021 |   2.93e-16   1.12e-15     0.26   0.795    -1.96e-15    2.55e-15
                2022 |  -6.73e-17   1.23e-15    -0.05   0.957    -2.55e-15    2.42e-15
                2023 |   2.65e-16   1.55e-15     0.17   0.865    -2.86e-15    3.39e-15
                     |
           c.egov#c.gdp |   5.19e-14   6.47e-14     0.80   0.427    -7.84e-14    1.82e-13
                     |
     c.internet#c.egov#c.gdp |  -9.13e-16   9.03e-16    -1.01   0.317    -2.73e-15    9.05e-16
                     |
       year#c.egov#c.gdp |
                2014 |  -2.34e-14   1.45e-14    -1.62   0.113    -5.25e-14    5.74e-15
                2015 |  -4.32e-14   2.39e-14    -1.81   0.077    -9.13e-14    4.96e-15
                2016 |  -1.57e-14   2.65e-14    -0.59   0.557    -6.91e-14    3.77e-14
                2017 |  -3.40e-14   3.56e-14    -0.96   0.344    -1.06e-13    3.76e-14
                2018 |   1.70e-14   6.07e-14     0.28   0.781    -1.05e-13    1.39e-13
                2019 |   8.75e-15   7.66e-14     0.11   0.910    -1.45e-13    1.63e-13
                2020 |   1.02e-13   1.28e-13     0.79   0.431    -1.56e-13    3.60e-13
                2021 |   6.33e-14   1.04e-13     0.61   0.547    -1.47e-13    2.74e-13
                2022 |   1.85e-14   1.03e-13     0.18   0.859    -1.90e-13    2.27e-13
                2023 |   5.99e-14   1.34e-13     0.45   0.658    -2.11e-13    3.30e-13
                     |
year#c.internet#c.egov#c.gdp |
                2014 |   4.38e-16   2.59e-16     1.69   0.098    -8.45e-17    9.60e-16
                2015 |   7.67e-16   4.43e-16     1.73   0.090    -1.25e-16    1.66e-15
                2016 |   5.18e-16   4.70e-16     1.10   0.276    -4.28e-16    1.46e-15
                2017 |   7.22e-16   5.32e-16     1.36   0.181    -3.49e-16    1.79e-15
                2018 |   1.51e-16   7.71e-16     0.20   0.846    -1.40e-15    1.70e-15
                2019 |   2.18e-16   9.40e-16     0.23   0.818    -1.67e-15    2.11e-15
                2020 |  -7.77e-16   1.48e-15    -0.52   0.603    -3.76e-15    2.21e-15
                2021 |  -4.47e-16   1.26e-15    -0.36   0.724    -2.98e-15    2.09e-15
                2022 |   3.11e-17   1.34e-15     0.02   0.982    -2.67e-15    2.73e-15
                2023 |  -4.15e-16   1.67e-15    -0.25   0.805    -3.78e-15    2.95e-15
                     |
                _cons |   .8436011   .0140302    60.13   0.000     .8153428    .8718595
-------------+----------------------------------------------------------------
              sigma_u |   .12481907
              sigma_e |   .00550574
                  rho |   .99805811   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

1. internet_lag2 (2-Year Lagged Internet Penetration)

- Coefficient: 0.000051
- P-value: 0.670
- Impact: The 2-year lag of internet penetration has a very small positive estimated effect on HDI. However, this effect is not statistically significant ($p > 0.05$). This means we don't

have enough evidence to conclude that past internet penetration (from two years prior) has a significant impact on current HDI levels in this model.

2. egov (Contemporaneous E-government Index)

- Coefficient: 0.0011987
- P-value: 0.956
- Impact: The contemporaneous e-government index has a small positive estimated effect on HDI. However, this effect is also not statistically significant ($p > 0.05$). Therefore, we cannot conclude that the current level of e-government significantly influences the current HDI in this model.

3. gdp (Contemporaneous GDP)

- Coefficient: 8.88e-16
- P-value: 0.680
- Impact: GDP has a very small positive estimated effect on HDI. This effect is not statistically significant ($p > 0.05$). This suggests that, in this model, current GDP does not significantly predict current HDI.

4. Year Dummies (year)

- Coefficients: Varying, some positive, some negative.
- P-values: Most are < 0.05 (statistically significant).
- Impact: The year dummies indicate how HDI in each year (2016-2023) differs from the base year (likely 2014). The significant p-values show that there are statistically significant differences in HDI across these years, even after controlling for the other variables.

5. _cons (Constant)

- Coefficient: 0.8277862
- P-value: 0.000
- Impact: This is the estimated HDI when all independent variables are zero. It's statistically significant, but its direct interpretation isn't always practically meaningful.

In summary, this model with a 2-year internet lag finds that neither lagged internet, contemporaneous e-government, nor contemporaneous GDP significantly predicts HDI. However, there are significant year-to-year variations in HDI.

Cluster Simplified Model Interaction FE robust 2y-lagged (without egov)

```
. xtreg hdi L2.internet c.L2.internet#c.gdp gdp i.year, fe vce(cluster country_id)

Fixed-effects (within) regression               Number of obs      =       414
Group variable: country_id                      Number of groups   =        46

R-squared:                                      Obs per group:
     Within  = 0.5624                                         min =         9
     Between = 0.0314                                         avg =       9.0
     Overall = 0.0328                                         max =         9

                                                F(9, 45)           =         .
corr(u_i, Xb) = 0.0582                          Prob > F           =         .

                                    (Std. err. adjusted for 46 clusters in country_id)
------------------------------------------------------------------------------
             |               Robust
         hdi |      Coef.   Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
    internet |
         L2. |   .0000892   .0001154     0.77   0.444    -.0001433    .0003217
             |
cL2.internet#|
  c.gdp      |  -6.55e-17   1.64e-17    -3.99   0.000    -9.85e-17   -3.25e-17
             |
         gdp |   8.73e-15   3.48e-15     2.51   0.016     1.73e-15    1.57e-14
             |
        year |
        2016 |   .0033928   .0004405     7.70   0.000     .0025056     .00428
        2017 |   .0063401   .0005445    11.64   0.000     .0052433    .0074369
        2018 |    .009229   .0008113    11.38   0.000      .007595    .0108629
        2019 |   .0127938   .0009464    13.52   0.000     .0108876       .0147
        2020 |   .0090614   .0011432     7.93   0.000     .0067588    .0113639
        2021 |   .0100561   .0012153     8.27   0.000     .0076083    .0125039
        2022 |   .0147265   .0013949    10.56   0.000      .011917    .0175361
        2023 |   .0153934   .0016008     9.62   0.000     .0121693    .0186175
             |
       _cons |   .8216091   .0089057    92.26   0.000     .8036721     .839546
-------------+----------------------------------------------------------------
     sigma_u |  .12285974
     sigma_e |  .00521545
         rho |   .9982012   (fraction of variance due to u_i)
------------------------------------------------------------------------------
.
```

- **2-Year Lagged Internet Penetration:** The coefficient for the 2-year lag of internet penetration (internet) is 0.000154, with a standard error of 0.0001988. This effect is not

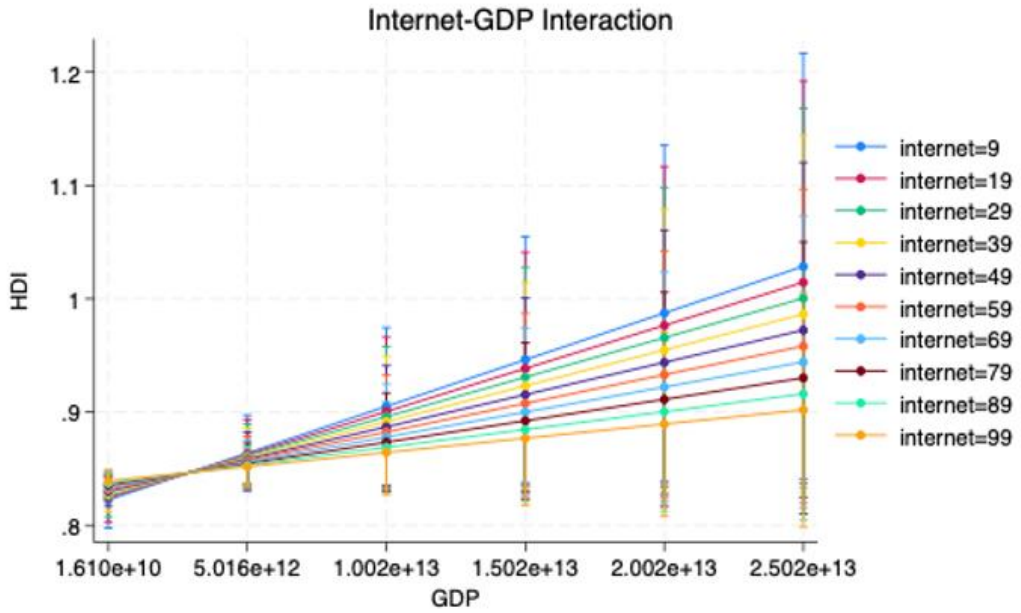
statistically significant (p = 0.446). This suggests that the 2-year lag of internet penetration does not have a statistically significant direct effect on current HDI in this model.

- **Interaction between Lagged Internet and GDP:** The coefficient for the interaction term between the 2-year lag of internet penetration and GDP (c.L2.internet#c.gdp) is -3.5e-17, with a standard error of 1.8e-17. This interaction effect is statistically significant (p = 0.055) at the 10% level, but not at the conventional 5% level. The negative sign suggests that the (unestimated) positive effect of lagged internet penetration on HDI may be slightly weaker in countries with higher GDP.
- **GDP:** The coefficient for GDP (gdp) is 7.37e-15, with a standard error of 2.96e-15. This effect is statistically significant (p = 0.012). This indicates that higher GDP is associated with higher HDI, even when accounting for the lagged internet and its interaction.
- **Year Dummies:** The coefficients for the year dummy variables (Year 2015 - 2023) are generally positive and statistically significant. This indicates that, on average, HDI has increased over the years in the sample period, relative to the base year (likely 2014, given the 2-year lag).
- **Model Fit:**
    - The within R-squared is 0.6214, indicating that the model explains 62.14% of the variation in HDI within countries over time.
    - The between R-squared is 0.0316.
    - The overall R-squared is 0.0328.
- **Fixed Effects:** The rho statistic (0.9978762) indicates that a large proportion of the variance in the error term is attributable to the country-specific fixed effects, further supporting the use of the fixed-effects model.
- **Correlation:** The correlation between the within errors and the within-group means of the predictors is 0.0852.

In summary:

This model, incorporating a 1-year lag for internet penetration and its interaction with GDP, shows that the lagged internet variable itself is not statistically significant at the 5% level. However, the interaction between lagged internet and GDP is marginally significant, suggesting a potential negative moderating effect of GDP. GDP has a significant positive effect on HDI, and there's a positive time trend in HDI. The high rho value underscores the importance of country-specific factors.

Margin Plots



Internet-GDP Interaction: The positive slope indicates that higher GDP amplifies the positive effect of internet penetration on HDI. For each GDP level, increased internet access correlates with higher HDI, with this effect strengthening as GDP rises.

Recommendations and Conclusions

Based on the analysis of the relationship between digital transformation, GDP, and HDI, the following recommendations can be made:

1. Integrated Digital Development Strategies:

- The findings consistently emphasize that the impact of internet penetration on HDI is enhanced in countries with well-developed e-government systems. Therefore, policymakers should prioritize integrated digital development strategies that simultaneously invest in expanding internet access and improving digital governance. This includes developing user-friendly online public services, ensuring digital inclusion, and building digital skills within the population. Rather than focusing solely on infrastructure, governments should also invest in the development of digital services and platforms that can effectively leverage increased internet connectivity to improve citizens' lives.

2. Context-Specific Approaches:

- The analysis reveals that the relationship between digital transformation and HDI is complex and context-dependent. Policymakers should avoid a one-size-fits-all approach and tailor their digital development strategies to the specific economic, social, and political conditions of their countries. In countries with lower GDP, policies should focus on addressing fundamental development challenges alongside digital initiatives, as the impact of internet penetration on HDI may be limited without improvements in basic living standards.

3. Long-Term Perspective:

- The inclusion of lagged effects and year fixed effects in the analysis highlights the importance of considering the time dimension in assessing the impact of digital transformation on HDI. Policymakers should adopt a long-term perspective and recognize that the benefits of digital investments may take time to materialize. They should also be prepared to adapt their strategies in response to evolving technological landscapes and global events.

4. Further Research and Data Collection:

The study identifies some counterintuitive findings, such as the negative main effect of internet penetration in some models. Further research is needed to explore these complex relationships and identify potential omitted variables or alternative model specifications that can provide a more nuanced understanding of the impact of digital transformation on HDI. Continued efforts to improve data collection and measurement in the area of digital development are essential for informing evidence-based policymaking. This includes gathering more granular data on digital access, usage, and skills, as well as data on the quality and effectiveness of digital services. By implementing these recommendations, governments can maximize the potential of digital transformation to contribute to sustainable human development and improve the well-being of citizens.

To conclude, the study suggests that the translation of digital transformation into tangible gains in human development is not automatic. Instead, it is contingent upon the presence of complementary factors, particularly a well-functioning e-government system, and is influenced by broader economic and temporal contexts. Policies aimed at enhancing human development through digital transformation should therefore adopt an integrated approach, simultaneously

fostering digital infrastructure and digital governance, while also considering the specific economic and temporal realities of individual countries.

Appendix: Comparison Table

Model	Internet	E-government (Egov)	GDP	Interaction Terms	Year Dummies	Model Fit (R^2)
Base OLS Naive Regression	Positive, Significant	Positive, Significant	Not Significant	None	Significant	R^2 = 0.8738, Adj. R^2 = 0.8705
Two-way Fixed Effects with Robust Standard Error	Not Significant	Not Significant	Not Significant	None	Significant	Within = 0.6424, Between = 0.6412, Overall = 0.3647
Cluster Simplified Model Interaction FE Robust	Collinear, Effect not estimated	Not Significant	Positive, Significant	Internet x Egov: Not Significant Internet x GDP: Negative, Significant	Significant	Within = 0.6523, Between = 0.1691, Overall = 0.1546
Cluster Simplified Model Interaction FE Robust (without Egov)	Positive, Significant	N/A	Positive, Significant	Internet x GDP: Negative, Significant	Significant	Within = 0.6087, Overall = 0.1311
Cluster Simplified Model Interaction FE Robust 1-year Lagged	Not Significant	Not Significant	Positive, Significant	Internet (lagged) x Egov: Not Significant Internet (lagged) x GDP: Negative, Significant	Significant	Within = 0.6106, Between = 0.1650, Overall = 0.1379
Cluster Simplified Model Interaction FE Robust (without Egov) 1-year Lagged	Not Significant	N/A	Positive, Significant	Lagged Internet x GDP: Negative, Significant	Significant	Within = 0.6071, Between = 0.0659, Overall = 0.0679
Cluster Simplified Model Interaction FE Robust 2-year Lagged	Not Significant	Not Significant	Not Significant	Complex interactions, mostly not significant	Significant	Within = 0.5445, Between = 0.1847, Overall = 0.0767
Cluster Simplified Model Interaction FE Robust 2-year Lagged (without Egov)	Not Significant	N/A	Positive, Significant	Lagged Internet x GDP: Negative, Marginally Significant	Significant	Within = 0.6214, Between = 0.0316, Overall = 0.0328

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