RESEARCH ARTICLE

DIFFUSION OF THE INTERNET AND DIGITAL DIVIDE IN POST-SOVIET COUNTRIES

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Abstract : This study explores the diffusion process of internet in countries, that were previously known as the USSR and currently are divided into 15 countries. Utilizing the S-shaped logistic curves, this paper forecasts the future trends of internet diffusion in these economies. Data were varying in range with each country having a different time frames on similar variables. The Logistic Curves for each country determined the length of time of internet diffusion,maximum carrying capacity, and different stages of the diffusion process, namely, emerging, growth, maturity, and saturation.The results showthat all countries have exceeded the emerging and growth phases, with 13 countries having reached the saturation point. It was also revealed that more years were utilized in the emerging phase relative to the growth and maturity phase confirming Rogers' thought that even with obvious advantage, the adoption process is complex at the beginning. Further, income levels proved important to the internet diffusion trajectory of countries since high-income countries outperformed middle-income countries. Estonia emerged as the pinnacle of internet diffusion among the 15 countries for reasons related to futuristic policies and approaches to policy implementation. Telecommunication infrastructure emerged as the most important determinant of internet diffusion in a country, across all income groups, which has further important implications for policymakers.

Keyword: Internet Diffusion, High-tech Innovation growth, post-Soviet countries

DOI : **10.5281/zenodo.17178000**

Introduction

The internet is believed to have evolved in the 1960s as a means by which researchers in government shared information. During the initial stages, computers were bulky and stationary such that to share information between computers, users had to move from one computer to another or use magnetic computer tapes through the traditional postal system. The Internet Society claims that the initial documented account of networking-enabled social interactions was J.C.R. Licklider's 1962 memos from MIT, which outlined his "Galactic Network" concept, where he envisioned a globally connected computer network allowing universal access to data and programs, a concept akin to today's Internet.

Today, the platform has grown to encompass the entire socioeconomic space, allowing for interactions of various forms between individuals, businesses, and nations (Hoffman et al., 2004; Na et al., 2020). The 2023 Sustainable Development Goals (SDG) report acknowledges the need to increase access to digital technologies and investment in digital infrastructure to promote the achievement of SDG 9. However, the internet can be both a boon and a bane. On the upside, the internet promotes development through inclusion, efficiency, and innovation (World Bank Group, 2016), enhances productivity at the workplace (Najarzadeh et al., 2014; Nguyen et al., 2023), increases opportunities for job seekers (Denzer et al., 2021) and even improves life expectancy (Byaro et al., 2023). According to the World Bank Group (2024), when a job seeker has access to high-speed internet, the chances of being employed increase by as much as 13.2% and the overall recruitment rate of a company rises by 22%. In education, internet use has been argued to have made students' lives easier through the use of software and learning tools and has contributed to the progress of quality education (Haleem et al., 2022). The internet has also spurred innovation in digital technologies such as artificial intelligence (AI), robotics, Internet of Things (IoT), quantum computing (QC), and blockchain technology. On the downside, Gu et al. (2024) assert that internet addiction can negatively affect the physical and mental wellness of students, if not properly managed. Shrivastava et al. (2018) reported that internet addiction at the workplace also has adverse effects like workers forfeiting sleep, meals, personal hygiene, and family time. Vitak et al. (2011) found that at least one hour of internet use at the workplace is non-work related, while Restubog et al. (2011) revealed that 30%-50% of internet use at the workplace is for personal use rather than office work. This corroborates the assertion by Hsieh and Goel (2019) that growth of internet at the workplace decreases productivity.

Between 2018 and 2022, the global internet user base expanded by 1.5 billion individuals, culminating in a total of 5.3 billion users by 2022, which constitutes approximately two-thirds of the world's population (World Bank Group, 2024). The COVID-19 pandemic significantly speeded up the propagation of internet users, particularly in middle-income countries. In 2020, the proportion of global population utilizing the internet surged by 6%, equating to an additional 500 million users, primarily driven by mobility restrictions that necessitated a shift of activities to online platforms. Thanks to the Covid-19 pandemic and the ever-increasing adoption of the internet, the traditional work environment has taken a deep shift with remote work or hybrid working style burgeoning at workplaces. Forbes reports that as of 2023, 12.7% of all full-time employees work from home and 28.2% of work are in hybrid mode.

Despite extant studies on the determinants of internet use and access, very few can be found to have examined the diffusion pattern of internet in various territories. Estimation of the diffusion trajectory of internet is pertinent for expediting momentum through policy and infrastructural development. Keeping in mind the dearth of literature and motivated by the situational report that over 2 billion people globally have no or limited access (World Bank Group, 2024), we focus on the internet diffusion in the post-soviet countries. Secondary data sources revealed that there were extreme differences in internet penetration rate in the post-soviet region, as of 2021, ranging from a low of 29.4% in Tajikistan to 91% in Kazakhstan, Estonia, and Latvia (World Bank, 2021). The GSMA 2022 mobile connectivity index also showed a significant disparity in various dimensions and indicators, with the overall index score ranging from 35.25 for Tajikistan to 84.38 for Estonia.

The present study employed the Logistic S-curve that has been widely used for technological forecasting. The research aims to determine the highest carrying capacity, stage of internet diffusion, and length of period for each diffusion stage, for each country. We agree with Kucharavy and De Guio (2015) that in designing systems and processes, forecasting becomes indispensable to the extent that a decision to invest in new technologies relies on consistent forecasting and S-curves are reliable models to do so. This research also makes a significant contribution by showing the co-movement between the three phases of diffusion, which has not been demonstrated earlier in any existing studies. To organize the paper, the next sections are structured as follows. Section 2 presents the literature review and Section 3 details the research methodology. The results and discussions are in Section 4 while section 5 concludes the paper with policy implications.

Literature Review

2.1 Theoretical Background

Several theories exist to underpin technology diffusion and adoption research: Theory of Planned Behaviour (Ajzen, 1988); Technology Acceptance Model (Davis, 1989); Theory of Information Behaviour (Chatman, 1996); Unified Theory of Acceptance and Use of Technology ((Venkatesh et al., 2003), and many more. The present study focusses on the Diffusion of Innovation (DOI) Theory (Rogers, 1995). Rogers (1995, p.5)defined diffusion as "*the process by which an innovation is communicated through certain channels over time among the members of a social system*". By this definition, four elements are identified: the innovation itself, the communication channels, the time needed to communicate, adopt, reject, or grow the innovation, and a social system. Rogers noted that the extent to which an innovation is diffused rapidly or not, rests on its embedded characteristics such as its relative advantage, how complex it is to realise and use, how visible the innovation results are to individuals, how easy it is to experiment with, and the compatibility of the innovation with norms of the social system. Relatedly, Rogers also argued that "*more effective communication occurs when two or more individuals are homophilous*" (p.19).

The essence of time in the diffusion process carries a heavy weight (Rogers, 1995) since it represents the rate of adoption and aids categorization of the adopters as innovators, early adopters, early majority, late majority, or laggards. According to Rogers, the rate of adoption of most innovations follows an S-shape, which is based on the information flow and reduction in uncertainty in the process of diffusion. Wisdom et al. (2014) pointed out that the adoption process is complex and that the process of adoption typically begins with the acknowledgment of an existing need, followed by the search for potential solutions. This leads to preliminary decision to pursue the adoption of a particular solution, culminating in the final decision to proceed with its implementation. For this reason, Wani and Ali (2015) considered the DOI theory as one that considers an individual's perspective of need, central to the changes that bring about reinvention and new behavior.

2.2 Empirical Review

Diffusion of the internet could be caused by both internal and external factors, which could be related to Information and Communications Technology (ICT). Using data from 1997 to 2007 for the US and fitting through a logistic model, Kim (2011) predicted that the maximum adoption would not go beyond 70% if the prevailing patterns remained unchanged and he determined take-off period to be between 1995 and 1997 corresponding to an adoption rate of 10% and 20%. This period marked the early introductory phase of the graphical user interface, which corroborated with the finding of Rogers (1995) who had determined that innovation diffusion would normally begin with 10%-20% adoption rate. Bacha et al. (2024) applied multiple approaches including Logistics, Gompertz, and the Bass models, to study the adoption of broadband in Algeria. The data from 2003 to 2019 showed that adoption of broadband had suffered delay due to macroeconomic factors such as institutional quality and enrollment in higher education, resulting in a U-shaped growth of broadband adoption. For Sub-Saharan Africa, Oyelaran-Oyeyinka and Lal (2005) used GMM to identify factors that affect the diffusion of internet and highlighted the role of infrastructure.

In contrast, Quiban (2021) found that for ASEAN countries, internet diffusion followed an S-curve wherein most countries had already reached the peak of their diffusion, while others were at their saturation point. India is currently projected to grow to be one of the world's economic powers with its vast population where internet diffusion will play a big role in this transformation. Singh and Singh (2023) examined the diffusion of India from 1999 to 2020 applying the S-curve models (Logistic and Gompertz) as the analytical approach. Their study revealed that India's potential to attain universal internet access could occur in 2028-2029 and this finding aligns with numerous econometric predictions of the upside evolution of the Indian economy. In China, Li and Shiu (2012) found that the richer provinces in the Eastern region had a better diffusion rate compared to the less rich provinces clustered in the Western and Central regions.

In the European studies, Zatonatska et al. (2019)analysed the diffusion process of the internet and e-commerce across Austria, Poland, and Ukraine. Using the Bass model, Austria emerged as the country with the greatest internet diffusion limit having the potential to attain 87% usage by 2025. Ukraine also showed the highest growth rate 14% against 3% for Poland and 4% for Austria. A study under the World Bank's Policy Research Initiative by Andres et al. (2007) produced one of the early multi-country research on internet diffusion covering 199 countries with data spanning 1990 to 2004. Applying the S-Curve, they clustered the sample into low-income and high-income countries to show that the diffusion curve for low-income countries was steeper than for high-income countries. So, to stretch policies aimed at driving diffusion across both clusters of economic categories, competition in the supply side of internet services has to be carefully monitored. Earlier, Chong and Micco (2003) identified that the disparity between diffusion of internet in high-income economies and low-income countries could be traced to their digital infrastructure. Another interesting study by Lin and Wu (2013) found that diffusion of broadband is stage-distinctive for OECD countries where innovators and early adopters were mostly influenced by income and education level, while laggards and late majority countries were affected by broadband price.

Methods

Internet use was measured by the number of users per 100, obtained from the International Telecommunication Union (ITU) database. In order to provide a true representation of the findings, the data span differed on a country-by-country basis. Diffusion trends for internet across the 15 post-soviet countries was estimated by employing the logistic S-curve. Following Meyer et al. (1999), the internet users over time, p(t) is proportional to the population such that growth rate at time ‘t’ is defined as the derivative dP(t)/dt.

Mathematically, we can represent the logistic curve as:

$$P(t) = \frac{k}{1 + e^{-\alpha-\beta t}} \qquad (1)$$

Where $P(t)$ depicts the number of internet users over time ‘t’,
α signifies growth rate parameter and indicates steepness of the sigmoidal (S) curve;
k is the maximum value of the limit known as the carrying capacity or the saturation level of growth, showing how large the number of users will be at time ‘t’
β signifies the time the curve reaches $k/2$ or the growth midpoint which is also the inflection point in the growth path.

α can be replaced with a variable that specifies the time required for the trajectory to grow from 10% to 90% of the limit k. This new variable, ‘dt’ would represent the curve’s typical time duration. Similary, β can be replaced with a variable t_m to represent the point on the curve where 50% of k is attained such that P(t_m) = k/2. Then, algebraically, we can derive dt as

$$dt = \frac{\ln(81)}{\alpha} \qquad (2)$$

As described in Chen et al. (2011), the logistic equation (1) can then be denoted as:

$$P(t) = \frac{k}{1 + e^{-\frac{\ln(81)}{dt}(t-t_m)}} \qquad (3)$$

Based on the years of the life cycle of internet diffusion the stage of each country was determined as

Emerging	before 10%
Growth	10% to 50%
Maturity	50% to 90%
Saturation	after 90%

The logistic sigmoidal curve and its parameters can be represented as in Figure 1.

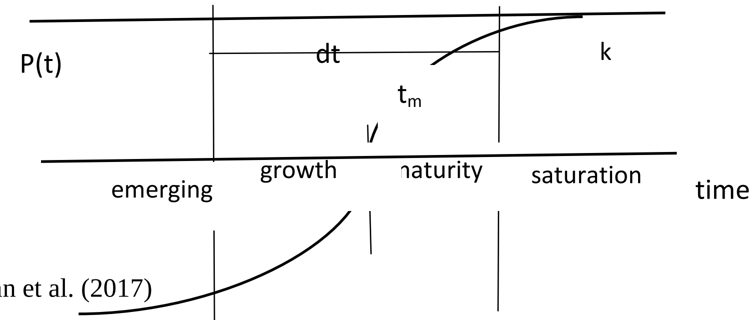

Figure 1:LogisticCurve and its parameters
Source: Rezaian et al. (2017)

The logistic S-curves were fitted for each country, and predictions were made within a boundary of 95% confidence levels. The software is Loglet Lab 4.0. The results of the logistic curve helped to classify each country according to their level of internet diffusion and the timescale of the growth of internet in the respective countries. These classifications were assigned numerical values such that “1” would signify a country that is below the emerging period of internet diffusion while “5” signified a country has achieved its saturation and the years beyond the saturation period were then assigned ascending numbers. In this manner, the categorical data was assigned numerical values and was transformed into ordinal data and this formed the basis of a categorical regression model (Meulman 2003) where the nonlinearity was based on the modification of the dependent variables such that the model permitted rankingthe dependent variable into ordinal categories (Majumdar and Pujari, 2022).

We thenused the general functional form for the regression analysis.
Internet Diffusion$_i$ = f (constant, predictor variables$_j$, factor variables$_k$, error) *(4)*
where
‘i’ =1, 2, 3… according to the level of internet diffusion level specified for each country;
‘j’ = country specific characteristics like per capita income.

‘k’ = factors that are related to internet diffusion like telecommunication infrastructure, human capital, etc.

Results and Discussion

4.1 Logistic S-Curve

The present study has been carried out across 15 post-soviet countries. The World Bank classification of these countries by income has been shown in Table 1 for the 2024 fiscal year.

Table 1: Income level of countries, based on World Bank (2022) classification

Classification	GNI per capita	Countries in Post-Soviet era
Low-income economies	Less than $1,135	
Lower middle-income	$1,136 and $4,465	Kyrgyz Republic
		Tajikistan
		Ukraine
		Uzbekistan
Upper middle-income	$4,466 and $13,845	Armenia
		Azerbaijan
		Belarus
		Georgia
		Kazakhstan
		Moldova
		Turkmenistan
High-income economies	$13,846 or more	Estonia
		Latvia
		Lithuania
		Russia

The logistic S-curves were fitted for each country, within a boundary of 95% confidence levels. Each country showed a different pattern of their S-curves which clearly indicated differences in the time and the growth rates for each country. Midpoint, in Table 2, shows that at the time of analysis (2024), all countries but for the Kyrgyz Republic (referred to as “Kyrgyz”) had reached 50% of their internet diffusion.

The fastest country to reach the inflection point was Estonia in 2003, and by 2010, five more countries had reached 50% growth - Latvia in 2005, Lithuania in 2006, Russia in 2009, Tajikistan and Azerbaijan in 2010. Aside from Kyrgyz, which outliers the sample growth pattern, Uzbekistan emerged as the latecomer. On an average, most countries in the post-Soviet era had obtained 50% internet adoption by 2011-2012.

Further, Table 2 reveals that different countries have taken different numbers of years to grow internet diffusion from 10% coverage to 90%. Kyrgyz, once again, emerged as the outlier country in the sample, as it took 25.3 years for the growth while Azerbaijan and Kazakhstan showed the lowest growth time, with 7.3 years and 8.8 years respectively. With the exception of Kyrgyz, the remaining countries took an average of 12.8 years to reach the 90% mark. The saturation point determined the maximum carrying capacity. Uzbekistan (104), Moldova (106), and Kyrgyz (260) show the potential of achieving the largest internet users per 100 people whereby the individuals are likely to use more than one internet account or hold service from multiple service providers. This implies that infrastructure policies need to be prepared to sufficiently accommodate the likely over subscriptions in these countries.

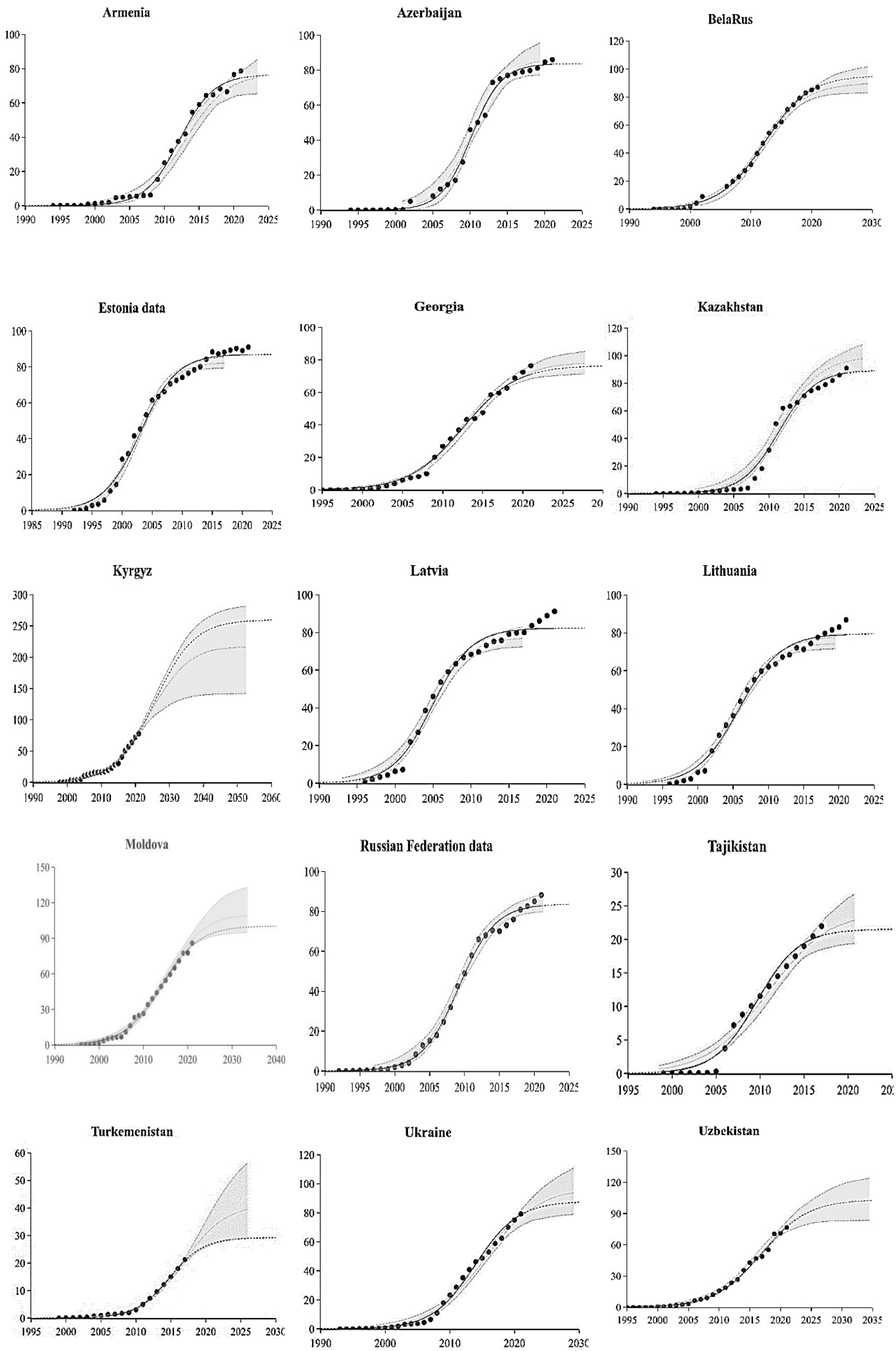

Figure 2: Logistic S-curves of internet diffusion for 15 post-Soviet countries

Table 2: Logistic growth parameters

Country	Midpoint (t_m)[a]			Growth time (Δt)[b]			Saturation (*k*)[c]				*F*-test
	Value	Min.	Max	Value	Min	Max	Value	Min	Max	R^2	*p*-value
Armenia	2012	2011	2014	11.3	9.6	18	77.5	69	97	0.953	0.000
Azerbaijan	2010	2009	2012	8.8	6.3	15	83.7	77	106	0.955	0.000
Belarus	2012	2011	2013	16.2	13	18	95.3	83	103	0.914	0.000
Estonia	2003	2002	2003	13.3	10	14	87	80	86	0.920	0.000
Georgia	2013	2012	2014	14.5	12	17	76.6	72	88	0.949	0.000
Kazakhstan	2011	2009	2014	7.3	6.4	18	81.3	65	107	0.974	0.000
Kyrgyz	2026	2019	2026	25.3	19	26	260	142	285	0.942	0.000
Latvia	2005	2004	2005	11.3	9.2	15	82.3	73	86	0.966	0.000
Lithuania	2006	2005	2006	13	10	15	79.6	72	79	0.945	0.000
Moldova	2015	2012	2015	19.4	14	20	106	81	109	0.963	0.000
Russia	2009	2008	2010	11.5	10	16	83.7	80	91	0.984	0.000
Tajikistan	2010	2009	2014	10.6	11	20	21.5	20	31	0.931	0.000
Turkmenistan	2015	2015	2019	10.6	11	15	29.3	30	64	0.975	0.000
Ukraine	2014	2014	2018	14.6	14	23	87.9	80	123	0.988	0.000
Uzbekistan	2017	2015	2018	16.7	13	20	104	83	129	0.984	0.000

Note:
[a]*Midpoint (t_m) is the time the growth of the internet reaches 50%;*[b]*Growth time (Δt) indicates the time (number of years) internet grows from 10% to 90% of its capacity;* [c]*Saturation (k) shows the point where growth reaches its carrying capacity; Min and Max represent the 95% lower and upper bounds estimated by bootstrapping; R^{2} is the coefficient of determination, and the p-value of the F-test shows the statistical significance of the model*

Table 3 shows the years of the life cycle of internet diffusion along with the stage of the life cycle for each country. Except Kyrgyz, all countries have crossed their maturity states and 13 out of the 15 countries have attained their saturation points. Kyrgyz took 13 years from the growth stage to the maturity stage and another 14 years from the emerging to the growth stage. In Table 4, we look into the number of taken by each country to go through the various stages of diffusion of the internet. On an average, the selected countries took 11 years to reach 10% growth from the year of launch of internet in their respective country. Estonia and Lithuania reached 10% within 7 years while Kyrgyz took the longest time. Consistent with the report by Kreitem et al. (2020), we find that countries like Armenia, Georgia, Azerbaijan, Ukraine, and Kazakhstan needed 10 years or more to cross the 10% point from the launch of internet. The years of growth from 10% to 50% and from 50% to 90% was the shortest for Kazakhstan.

Post-Soviet 1991, economic restructuring took the centre stage of government efforts, that was focused on real sectors like agriculture, industry, and services (Benešová & Smutka, 2016). Given the heavy effort to build the primary economy, the digital economy remained less improved as the move from a socialist to a market-driven economy needed time (Baimenov & Liebert, 2019). Moreover, the growth path faced numerous challenges including high unemployment, inflation, and heavy dependent of commodity exports (Benešová & Smutka, 2016).

Estonia was amongst the fastest to spread the use of internet among its citizens following the collapse of the Soviet Union which could be traced to the Principles on Estonian Information Policy in 1998. The policy was adopted by the Government of Estonia soon after the launch of the 1997 Tiger Leap Programme that was aimed at providing digital education infrastructure at schools through access to internet and development of digital technology (Runnel et al., 2009). By 2000, every Estonian school had computers and 75% of all schools had online internet connections and the others could use a dial-up option. Soon, Public Internet Access Points

(PIAPs) were established throughout the country followed by the launch of internet voting in nationwide elections by 2005(Kreitem et al., 2020; Runnel et al., 2009).

In Lithuania, the internet was launched in 1992 with the establishment of the first intercity communication channel between Vilnius University, Kaunas University of Technology, and the Institute of Mathematics and Informatics. By 1993, 6 universities, 11 research institutes, over 60 governmental organizations and NGOs began using internet services, especially for emails. Another significant push was the RAIN (Rural Area Information Network) project launched in 2004, which provided high-speed internet to all remote rural areas.

Tables 3 and 4, therefore, highlight that the adoption of internet in the post-soviet countries reveal substantial progress enhanced by policies favoring digital infrastructure that has resulted in significant increases in the number of individuals using the internet, an increased adoption of technology by businesses and government, and widespread use of digital devices such as smartphones and tablets. Data from World Bank database suggests that on an average, 75.5% individuals were using internet for the 15 countries, with 7 countries exceeding 85% usage.

Table 3: Years of the life cycle of internet diffusion and the type of stage

Country	Launch of Internet	Emerging (before 10%)	Growth (10%-50%)	Maturity (50%-90%)	Saturation (After 90%)	Stage in 2024
Armenia	1994	2001	2007	2012	2018	Saturation
Azerbaijan	1994	2001	2006	2010	2015	Saturation
Belarus	1994	1996	2004	2012	2021	Saturation
Estonia	1989	1989	1996	2003	2010	Saturation
Georgia	1995	1998	2005	2013	2020	Saturation
Kazakhstan	1994	2003	2007	2011	2015	Saturation
Kyrgyz	1998	1999	2013	2026	2039	Late Growth
Latvia	1990	1992	1998	2005	2012	Saturation
Lithuania	1992	1992	1999	2006	2013	Saturation
Moldova	1992	1995	2004	2014	2023	Early Saturation
Russian	1992	1997	2003	2009	2015	Saturation
Tajikistan	1990	1999	2004	2010	2015	Saturation
Turkmenistan	1999	2003	2009	2015	2021	Saturation
Ukraine	1993	1998	2006	2014	2020	Saturation
Uzbekistan	1999	1999	2008	2017	2026	Maturity

Note:

*A country is in the **Emerging stage** (early growth) if growth has not reached 10% in a year before the study year (2024)*

*A country is in the **Growth stage** if the internet growth is between 10% and 50% in a year before the study year (2024)*

*A country is in the **Maturity stage** if the internet growth is between 50% and 90% in a year before the study year (2024)*

*A country is in the **Saturation stage** if the internet growth reaches 90% or more in a year before thestudy year (2024)*

Table 4: Timescale of the phases of growth in internet

Country	Reaching 10% growth	No. of Years	Growth to Maturity	No. of Years	Maturity to Saturation	No. of Years	Total length
Armenia	1994-2007	13	2007-2012	5	2012-2018	6	24
Azerbaijan	1994-2006	12	2006-2010	4	2010-2015	5	21
Belarus	1994-2004	10	2004-2012	8	2012-2021	9	27
Estonia	1989-1996	7	1996-2003	7	2003-2010	7	21

Georgia	1995-2005	10	2005-2013	8	2013-2020	7	25
Kazakhstan	1994-2007	13	2007-2011	4	2011-2015	4	21
Kyrgyz Republic	1998-2013	15	2013-2026	13	2026-2039	13	41
Latvia	1990-1998	8	1998-2005	7	2005-2012	7	22
Lithuania	1992-1999	7	1999-2006	7	2006-2013	7	21
Moldova	1992-2004	12	2004-2014	10	2014-2023	9	31
Russian Federation	1992-2003	11	2003-2009	6	2009-2015	6	23
Tajikistan	1990-2004	14	2004-2010	6	2010-2015	5	25
Turkmenistan	1999-2009	10	2009-2015	6	2015-2021	6	22
Ukraine	1993-2006	13	2006-2014	8	2014-2020	6	27
Uzbekistan	1999-2008	9	2008-2017	9	2017-2026	9	27
Average		11		7		7	25

4.2 Regression Analysis

The functional form for the categorical panel regression was undertaken, following the equation

Internet Diffusion$_i$ *= f (constant, predictor variables*$_j$*, factor variables*$_k$*, error)* *(4)*

Where

Internet Diffusion= 1 denoted the country did not reach the “emerging” stage
= 2 denoted the country was between “emerging” and “growth”
= 3 denoted the country was between “growth” and “maturity”
= 4 denoted the country between “maturity” and “saturation”
≥ 5 denoted the country was beyond the “saturation” stage

Predictor Variable = per capita income

Factor Variables = e-Participation, Telecommunication infrastructure, Human capital Index, Mobile subscriptions

Data for Internet Diffusion was calculated from Table 3 which estimated the lifecycle of internet diffusion for each country. Per capita income for each country was obtained from the World Bank, using the GDP per capita, PPP (constant 2021). E-Government Development index (EGDI) has been calculated by the United Nations Division for public institutions and digital government which incorporates digital access characteristics to reflect how a country is using information technologies to promote access and inclusion to internet by its people. This database was used to take the components of EGDI, namely e-participation index, telecommunication infrastructure and human capital. The e-participation index is used to assess the degree of digitization of the country where the citizens use the internet to interact with the government and participate in policy and decision-making. The World Bank database was also used to procure the country-wise data on mobile cellular subscriptions per 100 people.

Multicollinearity and heteroscedasticity amongst the variables were checked using the variance inflation factor and the Breusch Pagan test respectively. The results (Table 5) show that there was no multicollinearity since the variance inflation factors are less than 10 for each variable. But robust regressions were used to tackle the presence of heteroscedasticity in the dataset as the null hypothesis of constant variance was rejected by the diagnostic test.

Table 5: Diagnostic Tests

	Variables	**Variance Inflation Factor**
Multicollinearity		
	Telecom Infrastructure	5.64

	Per capita GDP	4.23
	E-Participation Index	3.59
	Mobile subscriptions	2.61
	Human Capital	2.02
Heteroscedasticity	Ho: Constant variance	chi2(1) = 120.7 Prob > chi2 = 0.0000

Panel regression results are presented in Table 6. The full model included all 15 countries for the years 2003 to 2024. Thereafter, the countries were divided according to their income categories, based on Table 1. The Hausman test Chi^2 showed the fixed effects model would be appropriate in each scenario.

Table 6: Regression Results

	Coeff	Robust Std. Err	Coeff	Robust Std. Error	Coeff.	Robust Std. Err	Coeff.	Robust Std. Err
	FULL MODEL (FE)		HIGH INCOME (FE)		UPPER MIDDLE INCOME (FE)		LOWER MIDDLE INCOME (FE)	
Human Capital Index	-1.70418	3.2866	5.0986	5.532	.71993	1.9714	-5.0716	3.387
Telecom Infrastructure	**4.915****	2.1867	**7.7058*****	2.7072	**6.386*****	1.1306	**1.7508***	.71725
e-Participation	-.22715	.76922	-.087785	1.8337	-.67797	.70378	.717247	.411869
Per capita GDP	**.0004*****	.0000	**.0005*****	.000066	**.00016****	.000067	-.00001	.0003
Mobile Subscription	**-.0183*****	.00587	**-.0284****	5.7085	**-.01016****	.0047	.0077	.009587
constant	-1.2667	3.0898	**-13.686****	6.2147	-.54182	1.8538	**6.4825****	1.9601
Hausman Test Chi^2	138.25***		19.38***		402.75***		153.56***	
F Statistic	15.64***		73.90***		51.42***		19.05***	

Note: Dependent Variable is the Phase of Internet Diffusion; FE denotes Fixed Effects Model
*Significance level: ***denotes 99% level of significance, **denotes 95% level of significance, *denotes 90% level of significance*

The regression result showed in Table 6 helps to identify the significant factorsthat affect diffusion levels of the post-Soviet countries and the regression model addedanother layer of justification to the findings in this study.

For the full model with all the countries, the degree of Telecommunication infrastructure ($\beta = 4.915, p <0.05$) and Per capita GDP ($\beta = 0.0004, p <0.01$) significantly and positively contributed to the diffusion trajectory of post-Soviet countries showing that increasing the level of these predictors augment the diffusion process. However, and surprisingly, mobile subscription ($\beta = -0.0183, p <0.01$) was statistically and negatively significant asa determinant of internet diffusion. Additionally, human capital index and e-participation were not significantly impactful on the internet diffusion processes both in the full model and the income-level based models.

The panel regression was then applied for each income category separately, based on the segregation of Table 1. The impact of telecommunication infrastructure remained positive and significant across all income categories and emerged as an important factor for predicting the degree of internet diffusion in a country. Per capita GDP was also significant and positiveacross the countries while mobile subscription was statistically significant and negative as determinants of internet diffusion for all the post-soviet countries, except the lower middle income countries where these factors did not give any significant results. So, only telecommunication infrastructure emerged as the significant predicting variable explaining the internet diffusion among lower-middle income countries which indicatd that regardless of existing indicators, it may be difficult to roll out internet diffusion appropriately without a robust infrastructure in these countries.

4.3 Discussion of Results

Internet diffusion among the post-soviet countries revealed a progressively carved effort between the emerging stage and saturation stage. Given the full length of diffusion, the regression results which showed per capitaincome as a positive predictor of internet diffusion also defined the pace and lifecycle. On average, high-income countries recorded shorter diffusion length than those in lower income status.

It would be relevant for policymakers to note that telecommunication infrastructure emerged as the most dominant predictor of internet diffusion across all the models, and such represents an important policy directive and foundation for internet connectivity and deployment for all countries irrespective of economic status. Our results also reveal that to encourage internet diffusion in a country, the importance of telecommunication infrastructure is higher in high-income and upper-middle economies than in countries of lower-income status. These findings corroborate with the remarks ofOyelaran-Oyeyinka and Lal(2005)who emphasized that telecommunication infrastructure was of vital importance to internet connectivity, and this was true irrespective of per capita income levels. Consequently, the inequality in digital frameworks among countries explains the disparity in the rate of internet diffusion among countries.Lee and Leonard (2023)also highlighted that the infrastructure in support of internet connectivity is as important as physical infrastructure such as roads. It is foundational to both access and use and helps in bridging the internet gap among citizens.

Conclusion and Policy Implications

Since the launch of the internet and the diffusion of internet connectivity, economic activities of countries along with businesses and personal lives have relied heavily on it. In the space of evolving innovations, the importance of the internet is non-negotiable. For the 15 countries in our sample, the results show varying diffusion capacities in terms of the total number of yearsfor reaching saturation or full maturity. Countries like Estonia and Lithuania recorded impressive results in their diffusion offtake, due to the bold, quick, timely aggressive approaches which aided them to reach saturation levels faster relative to the other countries. Our results suggest that deliberate policy implementation is imperative to ensuring optimized internet diffusion.

The discussions highlighted the internet diffusion path of all 15 countries and we were able to show the stage each has attained as the reporting date. We have employed robust analytical techniques that fit the purpose of this study. Robust infrastructure emerged as the most important factor that defines the diffusion of internet services and explains the differences in the diffusion gaps amongst the post-Societ countries as well. The findings of the present study confirm that internet cannot be deployed without the requisite telecommunication infrastructure, regardless of factors like human capital or GDP or the e-participation levels encouraged by the national government. Therefore, policymakers and regulatory regimes must seek to support the development of the telecommunication industry by encouraging infrastructure enhancement and upgrading efforts needed to accelerate diffusion.

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