A New Index for Climate-Induced Migration Uncertainty

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Abstract

The impact of climate change on the world has been significant, leading to various efforts to reduce its risks. This study aims to create a new index to measure the uncertainty surrounding migration due to climate change. It uses a range of international newspapers with a global readership. Although climate change has increasingly influenced migration decisions in vulnerable areas, there is still a lack of quantitative research exploring this connection, which our study aims to address. The index indicates a growing trend in climate-induced migration decisions, especially over the last two decades, supporting the study's purpose. We also present empirical results that validate the depressing effect of the uncertainty index on per Capita GDP growth at global, regional and country-specific levels. The index has various practical applications and can be useful for future research.

Keywords: News, Climate change, International migration, Uncertainty, Predictability
JEL Codes: D8, D81, F22,

1. Introduction

Climate change is being manifested at an alarming rate globally, and it has constituted a source of concern to world leaders and policymakers – the most recent of which is the 2023 UN Climate Change Conference[4] hosted by the United Arab Emirates (UAE) in Dubai. Meanwhile, climate threats often accompany a growing number of global population changes and temporary displacements. The foregoing is exemplified by a significant number of Somalis who emigrated to Kenya's Dadaab refugee camp between 2011 and 2012 owing to drought and famine in the Horn of Africa. Similarly, statistics have shown that between 2008 and 2016, abrupt weather-related disasters forced an average of 21.5 million people to flee their countries annually, while dangers associated with the effects of climate change displaced thousands more people (UNHCR, 2017). The most common hazards that UNHCR responds to are related to climate change, including floods – 38%, earthquakes – 26%, and their engagement has been global, covering Asia, Europe, Latin America and Africa. According to the World Bank, by 2050, some regions, including Asia, Latin America and Africa, may jointly generate 143 million internal migrants due to climate change. Consequently, migration has been considered

[4] This conference comprises the 28th meeting of the Conference of the Parties (COP 28), which seeks to put nature, people, and livelihoods at the heart of climate action, fast-track the energy transition and slashing emissions before 2030, and transforming climate finance by delivering on old promises and setting the framework for a new deal on finance, among others.

and employed as a useful strategy for mitigating the risks associated with climate change, as it entails the movement of people and households, either temporarily (e.g., seasonal or circular migration) or long-term, as well as involuntary and often temporary displacement as a result of unforeseen circumstances including extreme weather events (see McLeman et al., 2021).

Quite a handful of attempts have been made to quantitatively conceptualize distinctly migration uncertainty (see Fraser and Ungor, 2019; International Organisation for Migration (IOM), 2023) and climate uncertainty (see Faccini, Matin, & Skiadopoulos, 2023; Gavriilidis, 2021); however, there is no study to the best of our knowledge that measures climate-induced migration uncertainty. Thus, we bridge this gap by constructing a new index establishing the link between climate change and migration. While Fraser and Ungor (2019) construct an index on migration-induced fear (due to security) and its associated socio-economic consequences, the IOM only relates the exposure of the human population to various climate risks[5]. Migration (domestic and international) in reaction to the effects of climate change can take several forms, from forced relocation in the event of imminent danger to mobility as a proactive adaptation strategy. Essentially, forced and abrupt migrations caused by climate change necessitate our construction of a global index to connect climate-related migration studies to more general economic fundamentals in order to promote synergy between academic research and migration-related policymaking.

Thus, we develop a news-based global quantitative indicator showing the intensity of climate-induced migration uncertainty from 1977Q4 to 2024Q1. Taking the lead from Narayan et al. (2021), multiple international newspapers with a global presence and readership are employed, and queries relating to climate, migration and uncertainty are subsequently utilised (see Table 1) to construct our index. This index would come in handy for policy-makers involved in housing and regional planning, as well as fiscal and monetary authorities, among others, in their quest to formulate integration policies necessary to mitigate climate-related migration risks. For example, in the course of the relocation, the housing needs of migrants evolve from needing emergency shelter to eventually relocating permanently to the receiving country and the ensuing integration that follows. Thus, housing and regional planners need to be fully ready to cushion the post-migration trauma orchestrated by climate change, and our index could be a pointer to this preparedness.

[5] https://www.migrationdataportal.org/climate-mobility-impacts

In Figure 1, we show the plot of our index. The plot depicts an upward trend in climate-induced migration uncertainty, and the spikes show various climate events associated with the rising forced migration. Additional plots involving migration-induced uncertainty and climate-induced uncertainty are respectively provided in Figures 2 and 3, and the observed movements highlight important events for the considered subjects. Finally, we provide some empirical results to assess the predictive contents of the developed index as well as the sub-indices, and the evidence supports their in-sample predictability for relevant macro fundamentals, particularly per capita GDP growth. Given this introduction, the rest of this paper is structured as follows. While Section 2 revolves around the data collection method, which includes keyword identification and selection of relevant newspapers as well as news text, we present an overview of the index in Section 3. Section 4 presents the results from the empirical application of how climate-induced migration uncertainty, as captured by the index, affects per capita GDP growth across different geographies and samples. Section 5 offers the likely future research agenda and concludes the paper.

2. Data Collection Methodology

The data collection process for this study comprises three integral steps: keyword identification, the meticulous selection of relevant newspapers, and the systematic download of news texts. Each step is meticulously designed to ensure the acquisition of pertinent data for a comprehensive analysis.

2.1 Keyword Identification

In this initial phase, we identify key terms vital to our research, resulting in three distinct term sets: Climate, Migration, and Uncertainty. These term sets are derived from previous works by Fraser and Ungor (2019) and Gavriilidis (2021), with subsequent modifications and additions to enhance relevance. The chosen keywords encompass a broad spectrum of factors related to climate change, migration, and uncertainty. The resulting comprehensive sets form the basis for an in-depth exploration of the interplay between climate, migration, and uncertainty. Note that the search process ensures that only articles that jointly report at least one keyword from each of the term sets (Climate, Migration, and Uncertainty) are considered. This process enables the connection of the three distinct terms that culminate into the intended index described as the climate-induced migration uncertainty index.

Table 1: Selected keywords for each of the components of the index

Climate	Migration	Uncertainty
carbon dioxide	border control	uncertainty
climate	Schengen	uncertain
climate risk	open borders	unstable
greenhouse gas emissions	migrant	fluctuation
greenhouse	migration	speculation
CO_2	asylum	complexity
emission	refugee	inconsistency
global warming	immigrant	unpredictability
climate change	immigration	volatility
green energy	immigration	
renewable energy	human trafficking	
environmental	emigration	
carbon footprint	displacement	
climate adaptation	resettlement	
climate mitigation.	integration	
extreme weather events	migrant workers	
adaptation strategies	border crossing	
mitigation efforts	displaced persons	
drought	deportation	
desertification	visa	
flood		
sea level rise		
environment		

2.2 Selection of Relevant Newspapers and News Text Downloads

There are myriads of international newspapers; however, our focus is to choose those that can truly represent global news readership. Thus, we adopt the list of 45 major international newspapers across various geographies by Narayan et al. (2021). This ensures that the data collected reflects global representation drawn from reputable and authoritative sources, adding an essential layer of validity and trustworthiness to the ensuing analysis (see Appendix 1 for the list of selected newspapers). This strategic selection enhances the credibility and trustworthiness of our data, derived from esteemed and authoritative sources.

Essentially, the scope of this study involves analysing climate-induced migration events using a wide range of international news sources. Thus, we selected newspapers with global accessibility, widespread readership, and the availability of accessible archives. Proquest TDM studio provides a robust database that meets those stipulated criteria. Contrary to probable concerns about underreporting substantial migration occurrences in non-English-speaking countries, the data shows a relatively balanced geographical distribution of sources, including newspapers from Europe (30.2%), Asia (27.9%), North America (27.9%), Oceania (11.6%), and Africa (2.3%). The distribution shows that the data sources used in this study represent a

global perspective with diverse sources from both English-speaking and non-English countries, but communicating to an international audience in English.

Moreover, it is crucial to emphasize that the countries represented by these newspapers are significant enough to report on climate-related events in their regions, thus covering various areas that contribute to the global economy (see Appendix 1). Additionally, we acknowledge that most of the newspapers considered are in English; it is important to note that any potential bias towards English-speaking media outlets is mitigated. Many of these newspapers, even those in other languages, maintain dedicated teams for translating news contents into multiple international languages, including English. For example, the BBC World Service operates in 42 languages, including English, across more than 200 countries and territories, with specialized news labs that utilize machine learning for translation and automatic transcription from various languages to English[6]. Similarly, other newspapers reporting on diverse events, including climate-related news, provide translations into English to reach a wider international audience. This argument aligns with Faccini et al. (2023)[7], whose global climate risk indices are similarly restricted to news articles written in English. Thus, our interest in this paper is primarily in large open economies that significantly contribute to global climate shocks rather than smaller countries with more localized climate concerns.[8]

Conforming to Proquest TDM studio search guidelines (2022), we end up with the following search term:

FULLTEXT(("carbon dioxide" OR climate OR "climate risk" OR "greenhouse gas emissions" OR greenhouse OR co2 OR emission OR "global warming" OR "climate change" OR "green energy" OR "renewable energy" OR environment OR environmental OR "carbon footprint" OR "climate adaptation" OR "climate mitigation" OR "extreme weather event" OR "adaptation strategies" OR "mitigation effort" OR drought OR desertification OR flood OR "sea level rise") AND ("border control" OR Schengen OR "open borders" OR migrant OR migration OR asylum

[6]See https://www.bbc.com/aboutthebbc/whatwedo/worldservice; https://slator.com/bbc-news-labs-runs-extensive-machine-translation-automatic-transcription-test

[7]Faccini et al. (2023) also focused exclusively on the stock markets of advanced economies that reflect the global economy in the empirical application of their (global) climate risk indices.

[8]In this regard, an example of the GVAR approach which incorporates a select group of large open economies whose shocks are impactful on the global scale, comes to mind (for more details, see Smith and Galesi, 2014; Chudik and Pesaran, 2016).

OR refugee OR immigrant OR immigration OR immigration OR "human trafficking" OR emigration OR displacement OR resettlement OR integration OR "migrant workers" OR "border crossing" OR "displaced persons" OR deportation OR visa) AND (uncertainty OR uncertainty OR uncertain OR unstable OR fluctuation OR speculation OR complexity OR inconsistency OR unpredictability OR volatility))

Similarly, for completeness, we also consider sub-indices involving climate-induced uncertainty and migration-induced uncertainty, which is particularly useful to those who may not be interested in the combined index. For instance, researchers in the field of agriculture may be more interested in using climate-induced uncertainty than migration-induced uncertainty or the combined index. We present below the full text of the search terms:

Climate Induced-Uncertainty

FULLTEXT(("carbon dioxide" OR climate OR "climate risk" OR "greenhouse gas emissions" OR greenhouse OR co2 OR emission OR "global warming" OR "climate change" OR "green energy" OR "renewable energy" OR environment OR environmental OR "carbon footprint" OR "climate adaptation" OR "climate mitigation" OR "extreme weather event" OR "adaptation strategies" OR "mitigation effort" OR drought OR desertification OR flood OR "sea level rise") AND (uncertainty OR uncertainty OR uncertain OR unstable OR fluctuation OR speculation OR complexity OR inconsistency OR unpredictability OR volatility))

Migration Induced-Uncertainty

FULLTEXT((“border control" OR schengen OR "open borders" OR migrant OR migration OR asylum OR refugee OR immigrant OR immigration OR "human trafficking" OR emigration OR displacement OR resettlement OR integration OR "migrant workers" OR "border crossing" OR "displaced persons" OR deportation OR visa) AND (uncertainty OR uncertainty OR uncertain OR unstable OR fluctuation OR speculation OR complexity OR inconsistency OR unpredictability OR volatility))

It is worth noting that these are the first climate-induced and migration-induced uncertainty indices developed from a global perspective, utilizing text mining with historical data. This approach aims to provide a broader understanding of the evolution of the relevant issues surrounding the subject matter. For example, Gavriilidis, K. (2021) has developed a text-based index focusing on climate uncertainty in the US economy. Similarly, Faccini et al. (2023) have

conducted a study offering a global perspective on climate uncertainty (although the issue of climate policy incorporated in the index among the global components is limited to the US). However, the study only covers the period from January 1, 2000, to December 31, 2018, which limits the historical perspective and may hinder a thorough analysis of how this uncertainty has impacted the global economy and our lives.

The migration uncertainty indices are specific to individual countries and are currently only available for France, Germany, the United Kingdom, and the United States. While these country-specific indices can help us understand each country's perspective on migration issues, they are limited to the four covered countries and do not allow for a broader, more representative analysis of the subject. Our data covers virtually all the known international newspapers from 1980 to 2024, providing a substantial observation of the evolution of uncertainty and offering insights for a deeper understanding of the topic.

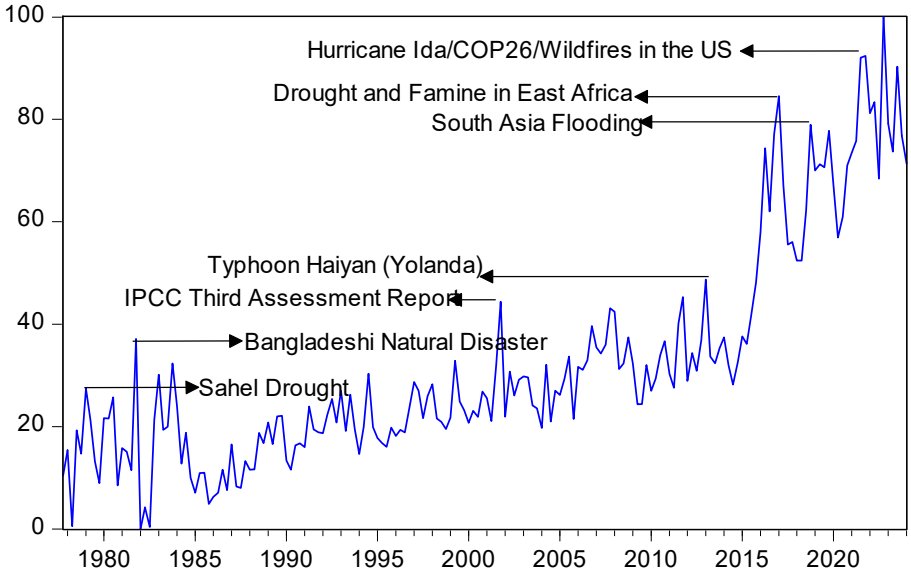
The search term is meticulously crafted to encompass the identified keywords. The resulting search query is executed across 45 international newspapers, and the ensuing dataset is systematically downloaded. Subsequently, employing the Proquest TDM platform's Jupyter notebook, text pre-processing techniques and preliminary analyses are executed on the acquired news.

3. An Overview of the Index

To construct the index, we do the following: (i) We count the number of newspaper articles with at least one term from each of the Climate, Migration, and Uncertainty term sets (see Appendix 2 for details on the total articles and those specific to the index) and then divide by the total count of newspaper articles (in the same calendar quarter for all the newspapers). (ii) We normalize the values from (i) using the formula [xnormalized =100* (x – x_minimum) / range of x] (where x is the value per quarter, x_minimum is the minimum value of x over the data scope) such that the values range between 0 and 100 with greater values implying rising uncertainty and the converse for lower values.[9]

[9] Note that range of x = xmaximum – xminimum.

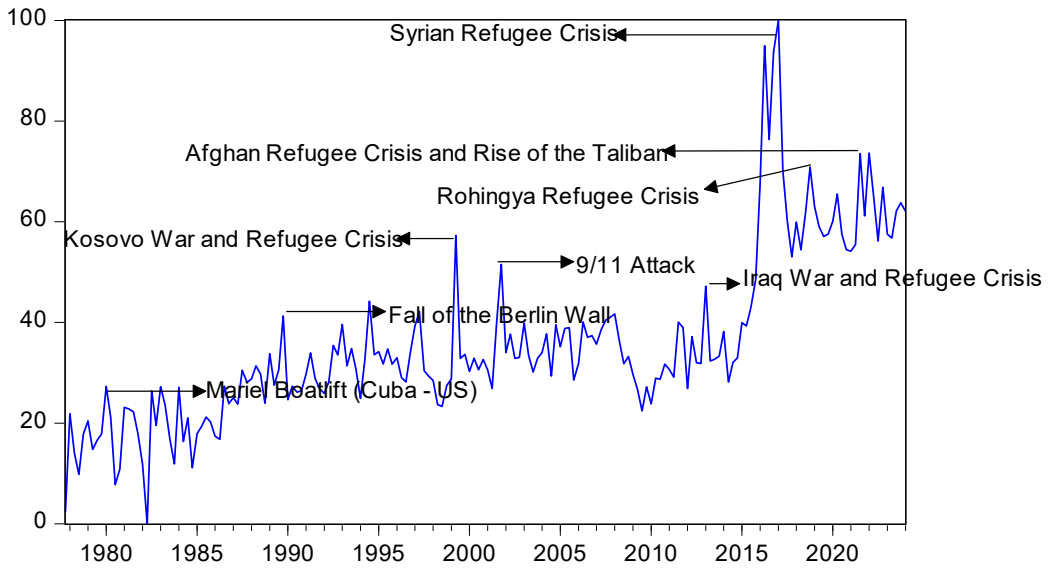
Figure 1: Trends in (global) climate-induced migration uncertainty



Our index shows climate-induced migration uncertainty has surged in recent years, with the most prominent spikes beginning only decades ago. The index captured some of the most devastating climate disasters that have resulted not only in loss of lives and property but also in mass migration of people. For example, the prolonged drought experienced in the Horn of Africa in 2016, which resulted in extreme food insecurity and mass displacement of people in Kenya, Ethiopia and Somalia, was appropriately captured in the index. Other serious natural disasters like hurricanes, flooding and wildfires, which generated serious concerns, especially in international media, were reflected in the index. The 2021 intense wildfires in the US, which led to forced evacuation, and Cyclone Fani, which displaced millions of people in India and Bangladesh in 2018 after being rendered homeless, are other examples of climate-induced migration events illustrated in the graph. It is worth mentioning that climate events taking place in large open economies (with very strong media), like the US and Australia, are likely to have more prominent representation in our index than those in small economies with less media presence, given the nature of our methodology. We attribute the marked differences observed in spikes in climate change now and in the past to two factors. One is the level of awareness of climate change issues, which has seen significant improvement in recent years, and two is the advancement in technology, which has seen the rapid development and adoption of social media through which the world has become more globalized.

We find our index to be validated by earlier studies like Simon Kuznets' environmental Kuznet Curve EKC. The EKC stipulates that in the early stages of economic growth, pollution emissions increase and environmental quality declines (Stern, 2018). Since the last three decades, there have been more newly industrializing countries whose activities have generally increased global warming and accelerated the rate of climate change, a phenomenon that explains the upward trending nature of our graph. According to Kuznets, the world is likely to witness an increase in climate-induced migration uncertainty as more countries industrialize, although this will eventually fall as industrialized countries become more environmentally responsible. Consequently, it is consistent to say that developed countries contribute or have contributed more to climate-induced migration uncertainty than others.

Figure 2: Trends in (global) migration-induced uncertainty

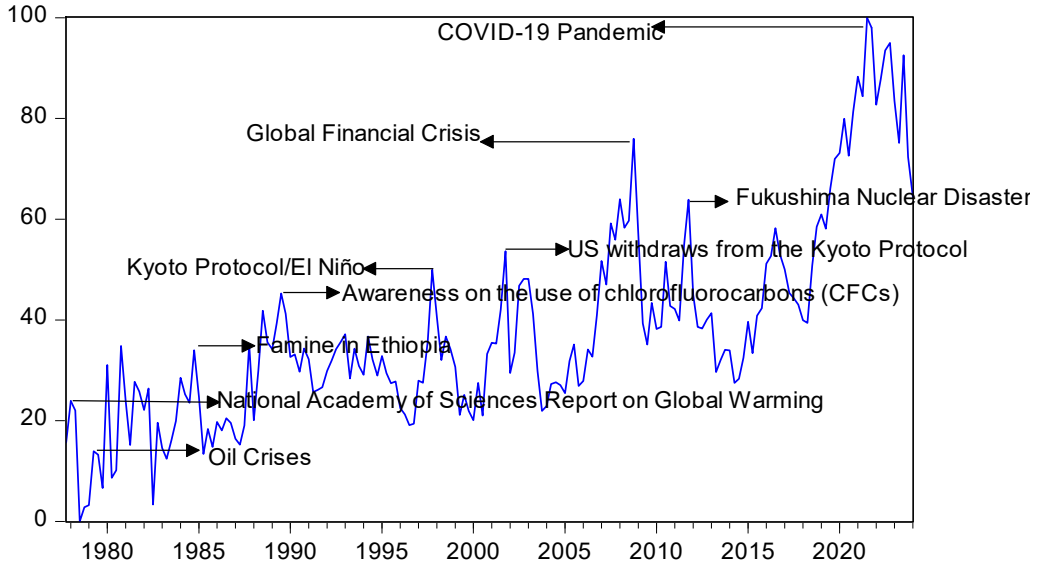


The graphical presentation of the Migration Uncertainty Index (MIU) reveals an upward trend in migration uncertainty over the years, with 2017 marking the peak. The index captures significant historical events, such as the Mariel Boatlift in 1980, where Fidel Castro's relaxation of border restrictions led to a mass emigration of Cubans to the US via the Mariel Harbor. Another notable event reflected in our index is the fall of the Berlin Wall in 1989, which saw tens of thousands of East Germans migrating to the West, drawing global media attention.

In 1999, the NATO bombing of Kosovo prompted millions to flee to neighbouring countries like Albania and Macedonia, becoming the largest migration event since World War II. The index indicates that this event received more media coverage than the 9/11 attacks. Other

significant spikes captured by the index include the 9/11 attacks, the 2003 Iraq War, the 2017 Syrian refugee crisis, and the 2021 Afghan refugee crisis, where thousands of Afghans fled to escape the new Taliban government.

Figure 3: Trends in (global) climate-induced uncertainty



Our Climate-Induced Uncertainty Index captures key climate issues reported in the news from 1978 to the 2020s. Notably, the late 70s and early 80s were marked by the oil crises, where reduced oil production in Iran and Iraq triggered a global recession. This event sparked a worldwide discussion on the climate impact of fossil fuels and the need for alternative, clean energy sources. Other significant climate issues of this period captured by our index include the Ethiopian famine and the 1978 report by the National Academy of Sciences on global warming. The publication of this report created more awareness and showed the media light on greenhouse gases and their attendant effect on climate change and global warming.

In the 1990s, our index also reflected the growing public awareness of the environmental risks posed by chlorofluorocarbons (CFCs) as seen by the spike and was well documented in the media. However, the most significant climate event of the decade was the 1997/1998 El Niño, which caused widespread droughts and flooding globally. This period also saw the introduction of the Kyoto Protocol, the first international conference to tackle climate change.

The 2000s experienced a surge in climate issues reported in the news, driven by the growing popularity of the internet. This decade witnessed more frequent and higher spikes in climate

news coverage compared to previous decades. The 2007/2008 global financial crisis marked a pivotal moment, with unprecedented discussions on climate change. In 2011, the Fukushima nuclear disaster in Japan became a major topic widely covered by the media. The 2020 COVID-19 pandemic further elevated climate discussions to new heights.

4. Empirical Application

4.1 Data and Method

Using our uncertainty indexes, we explore how the uncertainty surrounding climate-induced migration influences economic growth, specifically by examining the growth in per capita GDP. This aligns with the hypothesis that heightened uncertainty may lead to delayed investment decisions, which can ultimately hinder economic performance (see Baker et al., 2016; Gholipour, 2019; Shields & Tran, 2023). Our uncertainty index is measured quarterly, while per capita GDP growth is annual. The per capita GDP data is sourced from the World Bank Open Data, accessible online.[10] To ensure the reliability and/or robustness of our index, our analysis is conducted at global, regional, and country-specific levels. For the regional analysis, our focus is on the European Union, as it holds the position of the second-largest global economy. Additionally, we examine the United States as an individual country for our research, given its significant influence as a large open economy.

Methodologically, we employ the Autoregressive Distributed Lag – Mixed Data Sampling (ADL-MIDAS) model by Ghysels et al. (2002, 2006, 2007) to regress the annual GDP per capita growth of the global, regional and the country-specific sub-samples singly on the quarterly-based climate-induced migration uncertainty constructed. The ADL-MIDAS allows data sampled at different frequencies to be used in the same regression model. Therefore, our preference for the technique as the most appropriate in the context of this study lies in its ability to incorporate the information in the higher-frequency data into the lower-frequency regression in a simple and parsimonious fashion (Ghysels et al., 2007). The simple MIDAS appears in a distributed lag form, given that the dependent variable in one period is explained by more than one lag of the (higher frequency) independent variable. In this paper, the dependent variable is annual frequency, while the independent variable is quarterly. This suggests that the dependent variable is observed once a year while the independent variable is observed 3 times in the same period. Thus, the ADL-MIDAS is suitable for our analyses compared to other variants of the MIDAS framework. A generic representation of the ADL-MIDAS model is given as follows:

[10] See https://data.worldbank.org/indicator/NY.GDP.MKTP.CD

$$y_t = X_t'\beta + f\left(\left\{X_{t/S}^H\right\}, \theta, \lambda\right) + \varepsilon_t \quad (1)$$

where y_t is the dependent variable, sampled at a low frequency, at date *t*; X_t is the set of regressors sampled at the same low frequency as y_t; $\left\{X_{t/S}^H\right\}$ is a set of regressors sampled at a higher frequency with S values for each low-frequency value. It is noteworthy that $\left\{X_{t/S}^H\right\}$ is not restricted to the S values associated with the current t as it may include values corresponding to lagged low frequency values. Other representations such as f is a function describing the effect of the higher frequency data in the lower frequency regression while parameters β, λ, and θ are the vectors of parameters to be estimated. In terms of the weighting scheme required to identify the parameters for the lagged predictor(s) in the ADL-MIDAS, we favour the Almon lag weighting (also called polynomial distributed lag or PDL weighting) as it is widely used to place restrictions on lag coefficients in autoregressive models, and is a natural candidate for the mixed frequency weighting given its flexibility. For each high frequency lag up to k, the regression coefficients are modelled as a p dimensional lag polynomial in the MIDAS parameters θ. We may write the resulting restricted regression model as:

$$y_t = X_t'\beta + \sum_{\tau=0}^{k-1} X_{(t-\tau)/S}^{H\,\prime}\left(\sum_{j=0}^{p}\tau^j\theta_j\right) + \varepsilon_t \quad (2)$$

where $X_{(t-\tau)/S}^{H}$ denotes the data τ high frequency periods prior to *t*; p is the Almon polynomial order, and the chosen number of lags may be less than or greater than s. Importantly, the number of coefficients to be estimated depends on the polynomial order and not the number of high-frequency lags.

4.2 Theoretical Leanings

Several theories have been proposed to explain the causes and effects of migration between countries (refer to Taylor, 1999; Nwajiuba, 2005; Castles, 2010; Mayda, 2010; Crush, 2016). Some attribute migration to political and economic difficulties in the countries of origin (push factors), while others link it to the availability of better opportunities in destination countries (pull factors). The push-pull theory suggests that poverty, unemployment, political instability, and insecurity drive people to leave their home countries, while better job opportunities, political freedom, and security attract them to destination countries (King, 2012; Dinbabo & Nyasulu, 2016). Additionally, various models explain both the initiation and continuation of

migration. The neoclassical theory emphasizes wage disparities as a key driver, motivating people to move from low-wage to high-wage regions (Massey et al., 1999). Meanwhile, the dual labor market theory argues that migration arises from labour demands in developed economies, with workers from less developed countries supplying that need (Piore, 1979).

Beyond push-pull and neoclassical migration theories, climate-related concerns have become a crucial factor in migration decisions. In this context, climate policy aims to enhance environmental quality by reducing carbon emissions resulting from the use of fossil fuels for example, in production processes. Thus, growing awareness from climate summits could discourage migration driven by economic motives, as countries navigate through stemming the tide of increased emissions as a results of increased investment due to higher migration. The subsequent risks associated with the foregoing may hinder real economic growth, particularly in destination countries, which are often developed economies. Therefore, we hypothesize that rising uncertainty around climate-induced migration will negatively impact global economic performance.

This hypothesis is rooted in the Environmental Kuznets Curve (EKC) theory, which explores the relationship between economic growth and environmental quality. In our case, the EKC suggests that an initial influx of labour and the accompanying carbon emissions due to migration will boost production but degrade environmental quality. However, as concerns over environmental sustainability grow, this positive relationship between migration and growth reverses. Essentially, as economies advance, societies become more environmentally conscious, adopting various climate policies. Consequently, environmental degradation decreases alongside economic activity. This pattern forms an inverted U-shaped curve, where economic growth and environmental damage first increase, then decline, as uncertainty surrounding climate-induced migration rises (see Appendix 3 for these illustrations).

4.3 Empirical results

We initiate our analysis by conducting a comprehensive examination of summary statistics, evaluating the new index and per capita GDP growth under different data samples – full sample, and the periods before and after the global financial crisis (see Table 2, Figure 3 and the ensuing discussions). Our findings show a significant increase in climate-induced migration uncertainty (CIMU) by more than 100% after the global financial crisis compared to before it, suggesting a potential impact of the crisis on CIMU. We also observe a decrease in the average global per

capita GDP growth after the global financial crisis, sparking our interest in a potential inverse relationship between CIMU and the global GDP per person growth rate. This intriguing possibility, if proven, could have profound implications for our understanding of the global economy. Figure 4 provides initial support for this idea, illustrating an inverse relationship between per capita GDP growth and the uncertainty index.

Also, we observe that the index becomes more volatile after the global financial crisis judging by the standard deviation, although the converse holds for the coefficient of variation. When looking at the distribution statistics, we notice that the index was mainly negative and leptokurtic before the global financial crisis, but the opposite is true after the crisis. Similar trends are observed for the sub-indices involving migration-induced uncertainty and climate-induced uncertainty.

Table 2: Summary statistics

	MIU index	**CIU index**	**CIMU index**	**GDP per capita Growth**
Full-Sample				
Mean	35.045	36.797	30.941	1.577
Std. Dev.	16.289	19.028	20.130	1.544
CoV	0.465	0.517	0.651	0.979
Skewness	1.306	1.146	1.341	-1.300
Kurtosis	5.462	4.535	4.370	6.525
Frequency	Quarterly	Quarterly	Quarterly	Annually
No. Obs.	181	181	181	46
Pre-GFC-Sample				
Mean	28.089	27.597	20.389	1.652
Std. Dev.	9.144	10.502	8.438	1.146
CoV	0.326	0.381	0.414	0.693
Skewness	-0.285	-0.096	-0.046	-0.719
Kurtosis	3.970	3.194	3.037	3.075
Frequency	Quarterly	Quarterly	Quarterly	Annually
No. Obs.	119	119	119	31
Post-GFC-Sample				
Mean	49.933	53.569	53.076	1.465
Std. Dev.	19.145	20.224	21.076	2.269
CoV	0.383	0.378	0.397	1.548
Skewness	0.583	0.864	0.357	-1.142
Kurtosis	2.760	2.560	1.893	4.192
Frequency	Quarterly	Quarterly	Quarterly	Annually
No. Obs.	55	55	55	14

Note: Std. Dev. is standard deviation while CoV is coefficient of variation calculated as Std. Dev./Mean. MIU index is Migration-induced uncertainty index; the CIU index is

Climate-induced uncertainty, while the CIMU index is Climate-induced migration uncertainty.

We go beyond the descriptive analysis to test the applicability of the index to the widespread hypothesis that uncertainty depresses economic activity. Presented in Table 3 is a regression result of the predictability prowess of our index on economic activity at the global, regional, and country-specific levels. To begin with, the migration-induced uncertainty (MIU) in isolation appears to exhibit no predictive potential in global economic activity, neither at the regional nor individual country levels. However, where the underlying source of the migration is due to climate threat, we show results that predict the negative effect of climate-induced migration (CIMU) on the per capita GDP growth of the global economy. We test and validate the robustness of this finding across the per capita GDP growth of regional block using the case of the European Union (EU) and at a country level using the case of the U.S. Indeed, our finding of the predictability of adverse effect of CIMU in the global economy finds support in the IMF published study by Beltran and Hadzi-Vaskov (2023), where higher climate-induced migration is associated with lower agricultural output and employment. In sum, considering the extent of climate-induced migration when formulating policies to influence the level of economic activity is crucial, given its far-reaching effects. This is due to the potential adverse effects of CIMU on the GDP per capita of individual countries, regions and the global economy.

Finally, unlike migration-induced uncertainty, climate-induced uncertainty reflects the climate-induced migration uncertainty index, which combines the two sub-indices in a way. One striking thing to note here is that the issue of migration only becomes important when the underlying source(s) are well understood and incorporated into formulating policies to mitigate migration uncertainty. The emerging issue of climate change as an important driver of migration or forced migration needs to be addressed in global discourse, and more compelling actions need to be taken by the international community to mitigate the effects of climate change, particularly on productivity.

Figure 4: Trends in the climate-induced migration uncertainty and per capita growth grates of the US, EU and the world

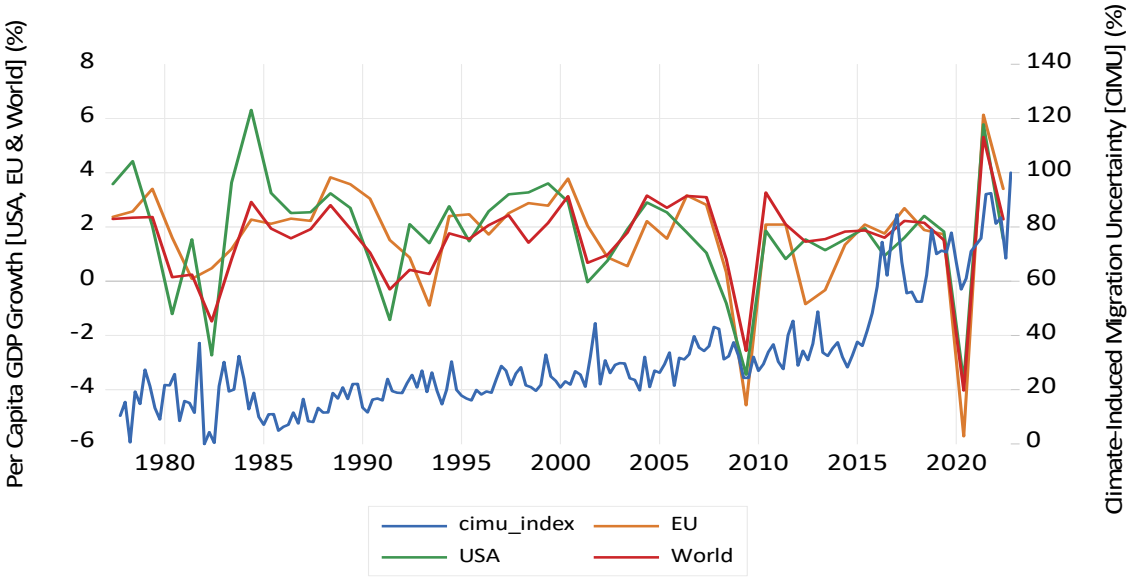


Table 3: Predictability results

Variable	CIMU Index	CIU Index	MIU Index
World			
C	1.2151*** (0.4305)	1.9319*** (0.5146)	1.1502* (0.6049)
PDL01	-0.2262** (0.1089)	-0.1965* (0.1026)	-0.0220 (0.1318)
PDL02	0.2344** (0.1075)	0.2263** (0.0983)	0.0339 (0.1233)
PDL03	-0.0473** (0.0215)	-0.0494** (0.0194)	-0.0079 (0.0238)
Average PDL	-0.0130	-0.0065	N/A
EU			
C	1.6320*** (0.5530)	2.5059*** (0.6486)	1.5532** (0.7664)
PDL01	-0.2402* (0.1399)	-0.1848 (0.1293)	0.0562 (0.1670)
PDL02	0.2620* (0.1381)	0.2325* (0.1240)	-0.0300 (0.1563)
PDL03	-0.0550** (0.0277)	-0.0535** (0.0245)	0.0026 (0.0302)
Average PDL	-0.0110	-0.0895	N/A
USA			
C	1.5012** (0.5529)	2.8065*** (0.6864)	1.7564** (0.8629)
PDL01	-0.4109** (0.1600)	-0.3054** (0.1528)	-0.0887 (0.1590)
PDL02	0.4183** (0.1533)	0.3293** (0.1483)	0.1031 (0.1481)
PDL03	-0.0842*** (0.0299)	-0.0699** (0.0294)	-0.0226 (0.0285)
Average PDL	-0.0256	-0.0153	N/A

Note: the average PDL, which involves summing up the coefficients, is only applicable to coefficients that are statistically significant. Hence, the term N/A means not applicable while ***, **, and * imply significance at 1%, 5%, and 10% levels of significance, respectively. The values in the parenthesis are the standard errors.

5. Conclusion and Future Research Agenda

The increasing frequency of climate-related disasters, which often pose life-threatening risks, has led to a rise in permanent migration for survivors. Hence, it is crucial to have an index that measures the uncertainty associated with climate-related migration. While there exist indices for climate and migration, we propose an index that links migration to climate-related events. This index can have several applications in research. Firstly, it can aid in the analysis and policy formation of housing markets since climate change can serve as a significant factor affecting housing supply. The index can help understand how climate-induced migration uncertainty impacts the supply of housing units and subsequently affects their prices. Secondly, the index can be useful when valuing domestic and international stocks, as it can be a risk factor influencing stock prices, returns and volatility as the stock market is a measure of macroeconomic performance in addition to economic growth used in our empirical exercise. Climate change affects the proper functioning of the financial system, which can lead to spillover effects on other sectors of the economy. Lastly, the index can initiate discussions on the need to address the adverse ecological effects of climate change, particularly as it relates to migration on a global scale.

Although the study uses newspapers from various continents, we acknowledge the underrepresentation of African sources in this study, with only 2.3% coming from Africa and that there may still be gaps in capturing migration events and climate-related impacts at a local level. Despite these limitations, the study aims to provide a broad perspective on climate-induced migration, and future research could address underrepresentation by including more local news sources and non-media reports. Furthermore, in many research studies involving taking samples from an entire population, generalizing findings from sub-samples to the broader population can present some challenges. This is particularly true when relying on English-language newspapers from various regions to build an index. This approach may result in the under-representation of significant climate events in areas where English is not the dominant language, posing yet another potential limitation for the study. Nonetheless, in our research, this issue is unlikely to be significant, as the region and country examined are large

enough to capture global climate concerns. Additionally, most international newspapers worldwide publish in English, reducing the risk of media coverage bias to a minimal level.

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Appendix 1

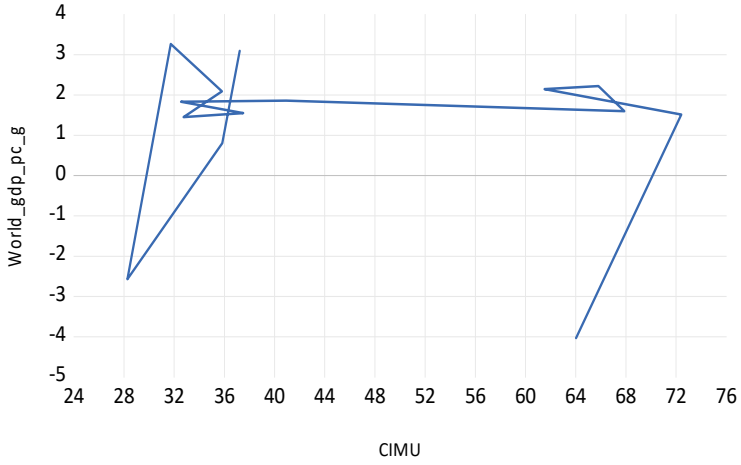
BBC	Press Trust of India
Manila Bulletin	Xinhua News Agency
The Australian	Kyodo News
The Guardian	The Hindu (India)
The Scotsman	The Wall Street Journal
The Irish Examiner	The Times (U.K.)
Australian Broadcasting Corporation	Jiji Press
The Canadian Press	The Telegraph (U.K.)
The Herald (Glasgow, Scotland)	The Daily Express (U.K.)
Calgary Herald	National Post
ArabianBusiness.com	EFE News Service
China Daily	Daily Mail (U.K.)
The Independent	Los Angeles Times
Times of India	Ottawa Citizen
Pakistan Press International Information Services	The Irish Times
All Africa	USA Today
Toronto Star	South China Morning Post
Kuwait News Agency (Kuna)	The New Zealand Herald
The Australian Financial Review	The Washington Post
Business World (Philippines)	Sputnik News Service
The Advertiser (Adelaide)	Irish Independent
The Globe and Mail	Chicago Tribune
The New York Times	

Appendix 2

S/N	Newspaper	News articles with at least one of the keywords from all the categories	News articles with at least one keyword from each of the category	Total news articles in the Database
1	Chicago Tribune	228,382 (Jan 01, 1985 to Aug 29, 2023)	1,169 (Mar 10, 1985 to Aug 03, 2023)	4,223,789 (Jan 01, 1985 to Aug 29, 2023)
2	BBC	363,142 (JUL 20, 1998 - AUG 28, 2023)	3,624 (OCT 06, 1999 - AUG 28,2023)	4,397,727 (JUL 20, 1998 - AUG 28, 2023)
3	Irish Independent	49,557 (Jun 22, 2006 to Sep 05, 2023)	294 (Jan 19, 2008 to Jul 24, 2023)	700,209 (Jun 16, 2006 to Sep 05, 2023)
4	The Washington Post	250,175 (Jan 01, 1987 to Sep 05, 2023)	3,825 (Jan 20, 1987 to Aug 24, 2023)	1,751,887 (Jan 01, 1987 to Sep 05, 2023)
5	The New Zealand Herald	50,799 (Dec 13, 2004 to Sep 06, 2023)	510 (Sep 09, 2005 to May 06, 2023)	462,887 (Nov 09, 2004 to Sep 06, 2023)
6	South China Morning Post	117,216 (Jan 01, 1993 to Sep 06, 2023)	1,200 (May 16, 1994 to Sep 03, 2023)	926,571 (Jan 01, 1993 to Sep 06, 2023)
7	USA Today	100,052 (Apr 01, 1987 to Sep 05, 2023)	964 (Apr 10, 1989 to Aug 19, 2023)	1,538,172 (Jan 01, 1915 to Sep 05, 2023)
8	The Irish Times	137,100 (Jan 02, 1995 to Sep 07, 2023)	941 (Feb 03, 1995 to Sep 02, 2023)	1,453,770 (Jan 02, 1995 to Sep 07, 2023)
9	Ottawa Citizen	145,730 (Sep 03, 1985 to Sep 06, 2023)	841 (Nov 09, 1985 to Aug 29, 2023)	1,638,276 (Sep 03, 1985 to Sep 06, 2023)
10	Los Angeles Times	328,233 (Jan 01, 1985 to Sep 07, 2023)	2,808 (Jan 01, 1985 to Sep 06, 2023)	3,678,523 (Sep 03, 1985 to Sep 06, 2023)
11	Daily Mail (UK)	295,555 (Dec 31, 1991 to Sep 07, 2023)	720 (May 13, 1998 to Sep 06, 2023)	5,179,324 (Dec 31, 1991 to Sep 07, 2023)
12	EFE News Service	39,649 (Apr 28, 2008 to Sep 09, 2023)	106 (May 07, 2008 to Apr 19, 2022)	3,146,995 (Apr 28, 2008 to Sep 09, 2023)
13	National Post	234,614 (Oct 27, 1998 to Sep 08, 2023)	2,299 (Jan 09, 1999 to Jul 26, 2023)	2,099,149 (Jan 01, 1992 to Sep 08, 2023)
14	The Daily Express (U.K.)	33,939 (Sep 05, 2015 to Sep 09, 2023)	81 (Jun 23, 2016 to Dec 03, 2022)	632,342 (Dec 30, 1992 to Sep 09, 2023)
15	The Telegraph (U.K.)	345,139 (Nov 05, 1831 to Sep 09, 2023)	3 776 49 (May 14, 1991 to Aug 22, 2023)	5,466,277 (Oct 22, 1831 to Sep 09, 2023)
16	Jiji Press	19,505 (Feb 12, 1998 to Sep 08, 2023)	28 (Nov 13, 2018 to Nov 13, 2018)	363,894 (Feb 12, 1998 to Sep 08, 2023)
17	The Times (U.K.)	426,682 (an 01, 1887 to Sep 08, 2023)	54 1,580 9 (Sep 22, 1923 to Jul 07, 2023)	6,323,096 (Jan 01, 1887 to Sep 09, 2023)
18	The Wall Street Journal	216,587 (Jan 02, 1984 to Sep 09, 2023	1,193 (Feb 17, 1984 to Jun 16, 2023)	2,280,469 (Jan 05, 1982 to Sep 09, 2023)
19	Kyodo News The Hindu	5,902 (Dec 13, 2013 to Apr 01, 2021)	51 (Oct 15, 2015 to Jul 08, 2020)	59,391 (Dec 13, 2013 to Apr 01, 2021)
20	Xinhua News Agency	198,631 (Jan 27, 1998 to Mar 02, 2022)	919 (Sep 10, 2002 to Feb 18, 2022)	2,613,614 (Jan 03, 1998 to Mar 02, 2022)
21	Press Trust of India	5,450 (Sep 01, 2010 to Mar 30, 2012)	21 (Feb 02, 2012 to Feb 02, 2012)	183,374 (Sep 01, 2010 to Mar 30, 2012)
22	The New York Times	77,186 (Aug 01, 1992 to Sep 10, 2023)	996 (Dec 11, 1992 to Aug 24, 2023)	475,015 (Aug 01, 1992 to Sep 10, 2023)

23	The Globe and Mail	371,565 (Nov 14, 1977 to Sep 12, 2023)	1,641 (Nov 18, 1977 to Sep 01, 2023)	4,713,430 (Nov 14, 1977 to Sep 12, 2023)
24	The Advertiser (Adelaide)	88,924 (Jan 01, 2001 to Sep 12, 2023)	354 (Mar 10, 2001 to Aug 12, 2023)	1,563,853 (Jan 01, 2001 to Sep 12, 2023)
25	Business World Philippines	12,723 (Jan 28, 2010 to Sep 12, 2023)	351 (Feb 24, 2018 to Oct 06, 2022)	105,903 (Jan 18, 2010 to Sep 12, 2023)
26	The Australian Financial Review	46,265 (Sep 02, 2013 to Sep 12, 2023)	782 (Sep 06, 2013 to Sep 12, 2023)	243,721 (Sep 02, 2013 to Sep 12, 2023)
27	Kuwait News Agency	19,375 (Sep 27, 2009 to Sep 11, 2023)	58 (Apr 27, 2010 to Jun 30, 2023)	233,362 (Sep 27, 2009 to Sep 12, 2023)
28	Toronto Star	213,692 (May 11, 1973 to Sep 11, 2023)	970 (Jul 20, 1986 to Sep 03, 2023)	2,124,444 May 11, 1973 to Sep 11, 2023)
29	All Africa	286,569 (Feb 06, 2009 to Sep 12, 2023)	3,636 (Mar 21, 2011 to Aug 14, 2023)	4,239,914 (May 11, 1973 to Sep 11, 2023)
30	30. Pakistan Press International Information Services	27,894 (Mar 05, 2010 to Sep 11, 2023)	221 (Mar 23, 2010 to Aug 09, 2023)	708,760 (Mar 05, 2010 to Sep 11, 2023)
31	Times of India	214,112 (Jan 06, 2006 to Sep 12, 2023)	592 (Mar 06, 2009 to Jun 23, 2023)	5,128,637 (Jan 06, 2006 to Sep 12, 2023)
32	The Independent	162,257 (Sep 30, 1993 to Sep 14, 2023)	1,739 (Aug 20, 1994 to Jul 12, 2023)	1,755,870 (Sep 30, 1993 to Sep 14, 2023)
33	China Daily	89,021 (Jan 02, 1995 to Oct 06, 2023)	1,385 (Apr 22, 1999 to Sep 14, 2023)	535,560 (Jan 02, 1995 to Oct 06, 2023)
34	ArabianBusiness.com	11,274 (Sep 11, 2008 to Sep 14, 2023)	167 (Jul 21, 2009 to Sep 14, 2023)	117,411 (Sep 10, 2008 to Sep 14, 2023)
35	Calgary Herald	133,892 (Dec 07, 1988 to Sep 13, 2023)	743 (Mar 12, 1989 to Feb 15, 2023)	1,499,916 (Dec 07, 1988 to Sep 13, 2023)
36	The Herald	115,629 (Jan 01, 1998 to Sep 14, 2023)	530 (Aug 01, 1998 to Jul 12, 2023)	1,438,382 (Jan 01, 1998 to Sep 14, 2023)
37	The Canadian Press	2,821 (Apr 30, 2010 to Oct 06, 2010)	1,860 ()	47,474 (Apr 30, 2010 to Oct 06, 2010)
38	Australian Broadcasting Corporation	21,160 (May 06, 2003 to Sep 12, 2023)	145 (Sep 03, 2004 to May 16, 2022)	113,188 (Apr 30, 2003 to Sep 13, 2023)
39	The Irish Examiner	46,360 (Apr 25, 2001 to Sep 14, 2023)	230 (Jan 06, 2003 to Jul 23, 2023)	589,035 (Apr 24, 2001 to Sep 14, 2023)
40	The Scotsman	67,609 (Feb 19, 1998 to Sep 14, 2023)	346 (Jul 11, 1998 to Jul 24, 2023)	690,524 (Feb 19, 1998 to Sep 14, 2023)
41	The Guardian	312,170 (Nov 28, 1807 to Sep 14, 2023)	3,865 (Mar 05, 1997 to Sep 14, 2023)	2,717,400 (Nov 28, 1807 to Sep 14, 2023)
42	The Australian	174,751 (Jan 01, 2001 to Sep 15, 2023)	782 (Feb 02, 2001 to Aug 25, 2023)	1,144,871 (Jan 01, 2001 to Sep 15, 2023)
43	Manila	19,718 (Sep 15, 2005 to Sep 15, 2023)	87 (Dec 16, 2018 to Jul 25, 2023)	234,221 (Sep 15, 2005 to Sep 15, 2023)

Appendix 3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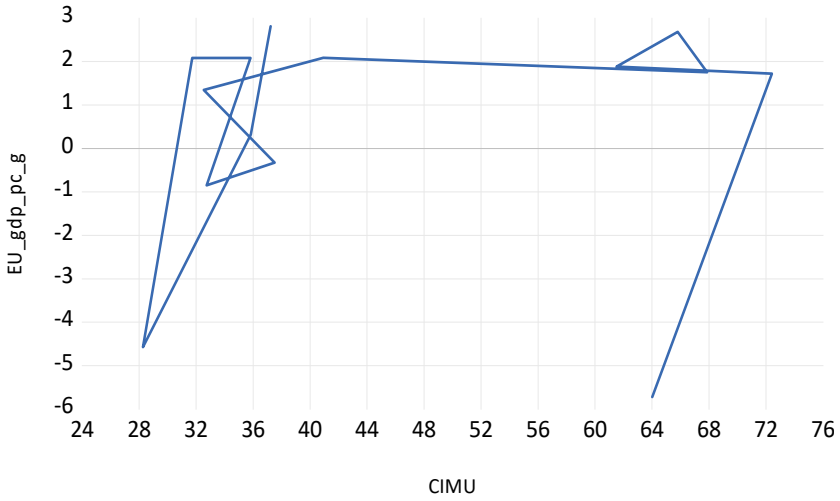
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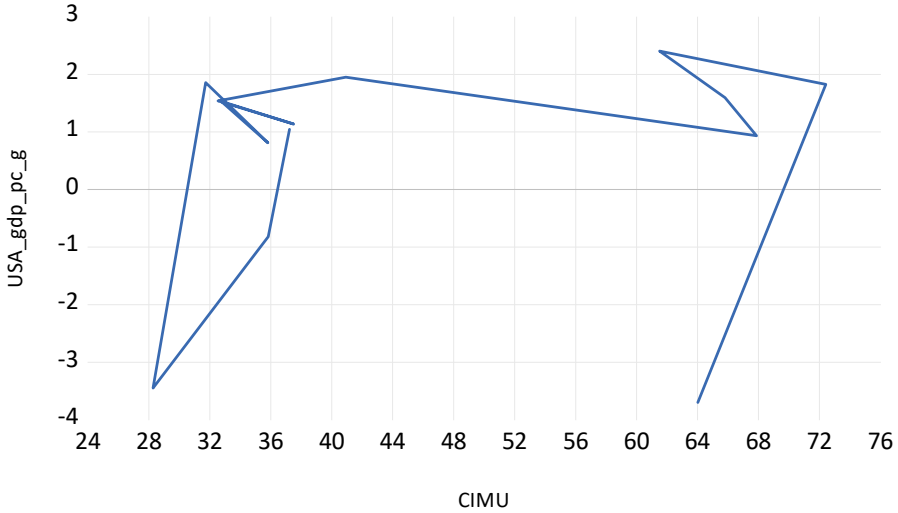
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