

Türkiye at the Crossroads: Climate Change Impacts and Internal Migration Determinants

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Abstract

The profound impact of climate change on human mobility is becoming increasingly evident. This study examines how climatic, economic, demographic, and spatial factors shape internal migration in Türkiye between 2008 and 2022. Using Random Utility and Gravity Model frameworks with Poisson Pseudo-Maximum Likelihood, Hausman-Taylor, and pooled OLS, we analyze the effects of temperature, precipitation, GDP, distance, and refugee presence on migration flows. We find that higher average temperatures and greater precipitation in origin cities are positively associated with migration. At the destination, temperature shows a positive association, while precipitation effects are mixed. Higher GDP per capita in origin regions is correlated with increased out-migration, whereas greater distance reduces migration, consistent with gravity model predictions. Furthermore, the influx of refugees influences local migration decisions by straining resources and heightening social tensions, prompting locals to migrate. Overall, the results underscore the importance of climatic and economic conditions, together with demographic pressures and spatial frictions, in shaping internal migration in Türkiye.

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1 Introduction

The impact of climate change on human migration patterns is a critical and emerging area of study, reshaping how we understand population movements in response to environmental stressors. Climate change is a global challenge acknowledged for leading to an increase in temperatures (Roberts et al., 2013; Bohra-Mishra et al., 2014; Cattaneo and Peri, 2016; Cai et al., 2016; Hirvonen, 2016; Nawrotzki et al., 2017; Burzyński et al., 2022), an alteration in precipitations (Fisher, 1925; Munshi, 2003; Coniglio and Pesce, 2015; Cattaneo et al., 2019), and a sea-level rise (Gray, 2009). Climate change is expected to intensify the severity and frequency of natural disasters, including droughts, floods, wildfires, and storms (Findley, 1994; Halliday, 2006; Reuveny and Moore, 2009; Koubi et al., 2016; Thiede et al., 2016; Dallmann and Millock, 2017; Ruiz et al., 2017; Murray-Tortarolo and Salgado, 2021; IPCC, 2022). This variety of impacts makes it hard to accurately predict how affected populations will respond, highlighting the difficulty in addressing the diverse ways climate change can affect people (Tol, 2002; Laczkó et al., 2009; Rummukainen, 2012; Joseph and Wodon, 2013; Noy, 2017). Rising global temperatures, shifting precipitation patterns, and the increasing frequency of extreme weather events are altering the viability of traditional livelihoods and prompting new migration responses. Understanding these patterns is vital for designing effective adaptation strategies and mitigating the socio-economic challenges posed by climate-induced displacement.

This paper investigates the influence of climate change on internal migration in Türkiye between 2008 and 2022. We employ Random Utility Model (RUM) and Gravity Models, estimated using Poisson Pseudo-Maximum Likelihood (PPML), Hausman–Taylor (HT), and pooled OLS, in order to address key methodological challenges such as zero migration flows, potential endogeneity, and unobserved heterogeneity. Our results show that rising temperatures in origin cities significantly increase out-migration, particularly in drought-prone areas. Higher precipitation in origin cities is also associated with greater migration flows, likely reflecting improved agricultural productivity and household incomes. Warmer temperatures and optimal rainfall conditions in destination cities attract more migrants. Additionally, economic factors such as higher GDP stimulate migration, while greater distances limit it due to increased migration costs. The influx of refugees further complicates local migration dynamics by straining resources and raising social tensions, prompting locals to migrate.

Climate change is increasingly recognized as a critical driver of migration, with rising temperatures and related environmental disruptions becoming major international concerns. As Cifci and Oliver (2018) notes, addressing climate change involves balancing urgent adaptation needs with non-trivial economic costs and potential impacts on development. International agreements such as the Kyoto Protocol and the Paris Agreement emphasize the global urgency of mitigating rising temperatures, which threaten ecosystems, settlements, and livelihoods. Within this context, migration has emerged as a central adaptation strategy and has sparked debate over the recognition of “climate refugees” (Black, 2001; Brown, 2008; Saldaña-Zorrilla and Sandberg, 2009; Feng et al., 2010; Dun, 2011; Nawrotzki et al., 2015; Jennings and Gray, 2015; Noy, 2017; Kaczan and Orgill-Meyer, 2020; Helbling and Meierrieks, 2021; IPCC, 2022; Thorn et al., 2023). Recognizing and supporting migration as a legitimate response to climate-induced changes is crucial, ensuring it remains a viable option for those impacted by environmental shifts (Stern, 2006; Coniglio and Pesce, 2015; Cattaneo et al., 2019; Beine and Jeusette, 2021; Burzyński et al., 2022).

Early work by El-Hinnawi (1985) categorizes environmental refugees¹ according to the type of displacement: temporary, resulting from short-term environmental stress; permanent, arising from enduring environmental change; or linked to gradual resource degradation. Migration drivers, however, are highly context-specific and shaped by the interplay of historical, economic, political, demographic, social, and environmental conditions in both origin and destination areas (Myers, 1993; Sasser, 2010; Black et al., 2011; Dun, 2011; Özden et al., 2011; Piguet et al., 2011; Jennings and Gray, 2015; Gray et al., 2020; Cattaneo et al., 2019; Erdoğan and Çantürk, 2022; Thorn et al., 2023). Black (2001) further underscores the significant scale of environmentally induced displacement and its profound effects on host regions, particularly in terms of resources and security. Myers (2002) warned that up to 200 million people could be displaced by 2050, particularly among populations at greatest risk from climate change (Brown, 2008; Biermann and Boas, 2010). More recently, Rigaud et al. (2018) projected that over 143 million people—around 2.8% of

¹Environmental migrants are persons or groups of persons who, for compelling reasons of sudden or progressive change in the environment that adversely affects their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and move either within their country or abroad.

the population in Sub-Saharan Africa, South Asia, and Latin America—may be forced to move within their own countries by 2050 as a result of climate change.

In recent years, Türkiye has experienced significant environmental and socio-political changes that have shaped internal migration patterns. The growing impacts of climate change, rising temperatures, declining precipitation, and more frequent weather anomalies, present complex challenges for the country, affecting economic stability (Özceylan and Coşkun, 2012; TMAD, 2022). Situated at the crossroads of Europe and Asia, Türkiye's location exposes it to the contrasting climatic and socio-economic dynamics of both regions, making it particularly vulnerable to climate-related risks. The country's diverse geography, with sharp variations in topography and climate over relatively short distances, produces substantial regional differences in socio-economic conditions. These variations complicate adaptation efforts and increase exposure to climate hazards, most notably droughts and floods, which directly reflect shifts in temperature and precipitation patterns. Wildfires have also become more frequent in recent years, though their impact on migration has been relatively limited compared to the broader influence of droughts and floods (Özceylan and Coşkun, 2012; Kiziroğlu, 2017; Benli et al., 2018).

Climate change significantly reduces agricultural output, leading to higher poverty levels and increased vulnerability (Schlenker and Roberts, 2009; Cai et al., 2016; Cattaneo and Peri, 2016). Extreme temperatures and droughts exacerbate these pressures, often heightening poverty and, in turn, contributing to conflict and displacement (Kelley et al., 2017; Selby et al., 2017; Chen and Mueller, 2019; Erdoğan and Cantürk, 2022). For example, Kelley et al. (2015) identify climate change as a contributing factor to the severe drought in Syria, which triggered substantial agricultural decline and economic instability, ultimately intensifying the conflict and producing a large wave of refugees. Türkiye has been directly affected by this dynamic, hosting nearly 5 million refugees, of which approximately 3.5 million are Syrians, according to the Republic of Türkiye's Ministry of Interior Presidency of Migration Management (RTMIPMM)². This large-scale influx has placed additional pressure on local resources, services, and labor markets, generating what is often described as a “refugee burden” and prompting further internal migration flows within Türkiye (Erdoğan and Cantürk, 2022). Beyond economic and demographic effects, migration also influences cultural proximity between host and home populations through compositional shifts and cultural diffusion, which may result in assimilation or, alternatively, in heightened cultural tensions (Rapoport et al., 2020). Such dynamics illustrate the secondary effects and displacements of climate change-induced migration, as increased strain on host regions contributes to both internal displacement and broader social challenges (Barrios et al., 2006; Joseph and Wodon, 2013).

We explore the effects of climate change and the influx of refugees, thought of as a form of secondary displacement of climate change, on internal migration patterns in Türkiye from 2008 to 2022.³ Our focus is on internal rather than international migration, as Turkish citizens face significant visa restrictions in accessing developed countries. This constraint parallels the concept of border frictions in gravity models, where institutional and geographic barriers limit cross-border mobility (McCallum, 1995; Anderson and Van Wincoop, 2003; Silva and Tenreyro, 2006; Anderson, 2013; Chen and Mueller, 2019).

We selected 30 provinces as origin cities⁴ from Türkiye's 81 provinces to represent internal migration patterns across diverse climatic, geographic, and socio-economic contexts. Within this sample, we identify 17 provinces as origin drought-affected cities to analyze migration responses to drought conditions, based on the classification by Cebeci et al. (2019) using the Bagnouls–Gaussien aridity index.⁵

We design our analysis using both RUM and the gravity model, which are widely applied in the study of migration flows under climate variability (Backhaus et al., 2015; Beine and Parsons, 2017). The gravity framework allows us to assess how temperature, precipitation, GDP levels, and geographic distance in both origin and destination cities shape migration, while RUM captures how individuals select destinations based on the highest expected utility. To estimate these models, we employ PPML, HT, and pooled OLS methods.

²Official statistics available at: <https://en.goc.gov.tr/>

³We start from 2008 due to the availability of migration data from the Turkish Statistical Institute.

⁴The logic behind the selection of cities depends on various factors. The first criterion is the extent to which the city is affected by climate change. The second criterion is the city's location in the southern part of Türkiye, which is closer to the main climate-affected areas close to the Equator. The third criterion considers the urbanization features versus rural characteristics.

⁵The Bagnouls–Gaussien index, also known as the aridity index, serves as a key metric for gauging climate dryness. Developed by Françoise Bagnouls and Henri Gaussien, it determines arid periods through a formula that contrasts temperature and precipitation data, making it crucial for analyzing the climatic impacts on ecosystems and various human activities, including the assessment of drought conditions.

PPML effectively addresses zero migration flows and heteroskedasticity, making it well-suited for the gravity specification. The HT estimator mitigates endogeneity concerns and allows the inclusion of both time-varying and time-invariant factors, such as distance. Pooled OLS serves as a baseline for robustness checks. We further include time-fixed effects, origin-fixed effects, and destination-fixed effects to control for unobserved heterogeneity and validate the reliability of our results.

Our estimations using pooled OLS, PPML, and HT consistently demonstrate the significant influence of climatic and economic factors on internal migration in Türkiye. Across both the full-country sample and the subset of drought-affected cities, higher origin temperatures significantly increase migration flows, in line with previous studies (Backhaus et al., 2015; Cai et al., 2016; Cattaneo et al., 2019). This effect is particularly strong in drought-prone cities, where extreme summer heat drives residents to seek more temperate destinations. Precipitation also exerts a positive influence on migration, likely reflecting higher agricultural yields and improved household incomes that provide the financial means to migrate (Hirvonen, 2016). Similarly, higher origin GDP is robustly associated with greater out-migration, underscoring the role of economic capacity in enabling mobility.

Distance emerges as another critical determinant, with longer distances significantly reducing migration flows due to higher costs of mobility (Beine and Parsons, 2015). This finding is consistent with the gravity model, which predicts a preference for geographically proximate destinations where social and economic ties are easier to maintain. Finally, the refugee burden has a substantial impact on local migration decisions. Both refugee-related policy shifts and the scale of refugee inflows indicate that the arrival of large refugee populations strains resources and intensifies social tensions, encouraging some locals to relocate that reflects the secondary displacement effects of climate change.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature, while Section 3 provides an overview of Türkiye. Section 4 outlines the methodology, and Section 5 describes the data and presents summary statistics. Section 6 explains the identification strategy, and Section 7 reports the empirical results, including robustness checks. Section 8 discusses the implications of the findings in relation to existing research and policy debates. Section 9 concludes with a summary and directions for future research.

2 Literature Review

The literature on climate change and migration has expanded rapidly over the past decade, attracting growing attention from the academic community (Berlemann and Tran, 2020; Beine and Jeusette, 2021; Backhaus et al., 2015; Beine and Parsons, 2017; Berlemann and Steinhardt, 2017). A number of studies have documented the direct impacts of climate change, such as rising temperatures and shifting precipitation patterns, on migration decisions (Backhaus et al., 2015; Cai et al., 2016; Cattaneo and Peri, 2016; Beine and Parsons, 2017; Berlemann and Steinhardt, 2017; Benveniste et al., 2022). These environmental changes are recognized as important drivers of migration, influencing the frequency and severity of natural hazards, including droughts, floods, sea-level rise, and wildfires (Suhreke and Hazarika, 1993; Halliday, 2006; Millock, 2015; Report; IPCC, 2022). Beyond environmental pressures, social and economic stressors also shape migration patterns (Ravenstein, 1885; Black, 2001; Özden et al., 2011; Cattaneo and Peri, 2016; Thorn et al., 2023). The complexity of these interactions makes it difficult to predict how affected populations will respond (Rummukainen, 2012; Joseph and Wodon, 2013). As Piguet et al. (2011) argue, climate change influences both the desire and the ability to migrate, making it challenging to determine whether environmental factors act directly or indirectly. For instance, rising sea levels have rendered Tuvalu uninhabitable, forcing migration, a direct effect of climate change (Campbell and Warrick, 2014). By contrast, climate-induced declines in agricultural productivity and income represent an indirect effect linking environmental change to migration (Coniglio and Pesce, 2015; Beine and Parsons, 2017).

Nordhaus (2019)⁶ highlights that climate change has become particularly critical since the early 2000s. While natural climate variability has produced temperature anomalies over the last half-million years, recent decades have witnessed sustained warming of both land and oceans, primarily driven by human activity.

⁶William Nordhaus was awarded the Nobel Prize in Economic Sciences in 2018 for integrating climate change into long-run macroeconomic analysis. His work has been pivotal in understanding the economic impacts of climate change and the importance of sustainable policies.

This warming alters temperature extremes, precipitation patterns, storm activity, snowpacks, river runoff, water availability, and ice sheets. Climate models predict a significant rise in global temperatures by 2100, making the consequences of continued warming unavoidable without major mitigation efforts (Nordhaus and Boyer, 2003; Nordhaus, 2013).

Figure 1 presents a reconstruction of global temperatures over the past half-million years based on Antarctic ice-core data. The series is normalized to the year 2000, set as the baseline of 0°C, and projections suggest that, without climate change mitigation policies, future temperatures will exceed the historical maximum of this period (Nordhaus, 2019).

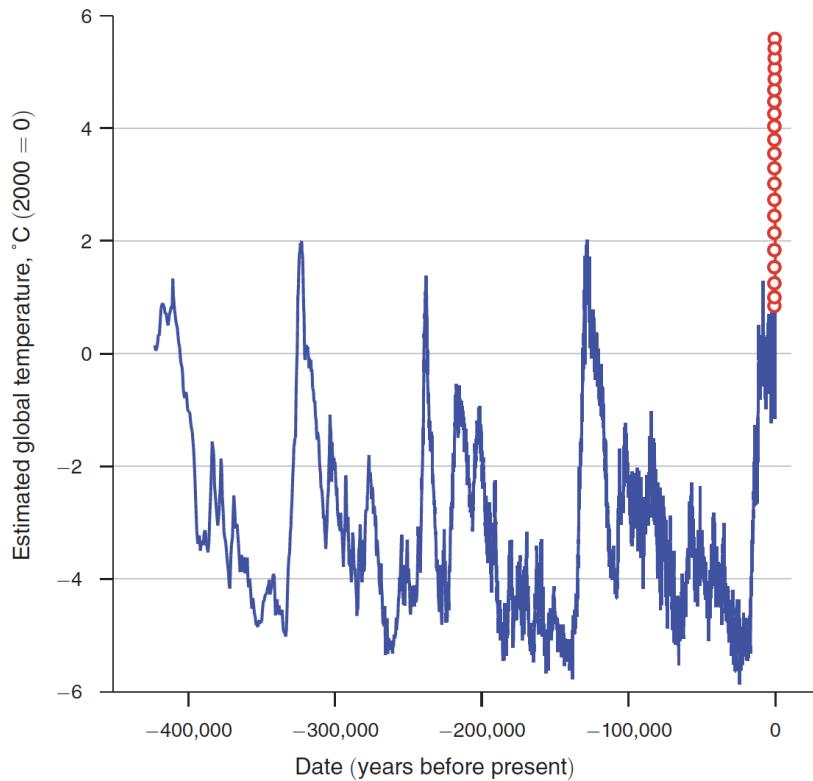


Figure 1: Estimated Global Temperature Changes Over the Past 400,000 Years

Note: Antarctic ice core data (solid line) and model projections for the next two centuries (circles).
Data Source: Nordhaus (2013, 2019)

The relationship between climate change and immigration is further elucidated through empirical studies and meta-analyses. Beine and Jeusette (2021) provides a pivotal meta-analysis examining a wide array of empirical studies, which reveals the diversity in outcomes and methodologies. Beine and Parsons (2015); Millock (2015); Ruiz et al. (2017); Berlemann and Steinhardt (2017); Moore and Wesselbaum (2023) provided vast literature on climate change and migration relationships.

Climate change boosts migration from low to high-altitude areas (Munshi, 2003; Moore and Wesselbaum, 2023). Research on environmental migration further highlights a North–South divide: while Northern regions benefit from stronger institutions and greater adaptive capacity, Southern regions face heightened climate risks that drive movements toward wealthier, less-affected areas such as the United States and Europe.(Barrios et al., 2006; Kharin et al., 2007; Rappaport, 2009; Sasser, 2010; Hijzen and Wright, 2010; Cattaneo and Peri, 2016; Piguet et al., 2018). According to Myers (2002), over 200 million people could be displaced by climate change by 2050. More recently, Rigaud et al. (2018) predicted that over 143 million people, or 2.8% of the population in Sub-Saharan Africa, South Asia, and Latin America will be forced to move within their own countries by 2050 as a result of climate change. In addition to population migration,

the economic implications of climate change, as analyzed by Nordhaus and Boyer (2000, 2003) indicate a substantial impact on human health, water quality, and livelihoods, with a projected impact of \$1 billion on the United States.

Rising temperatures have been shown to significantly influence migration by directly affecting individuals' living conditions (Bohra-Mishra et al., 2014; Beine and Parsons, 2017). Yet, this effect is not uniform: in middle-income countries, higher temperatures tend to increase out-migration, whereas in poorer countries they often reduce it, reflecting resource constraints that limit mobility (Cattaneo and Peri, 2016). Similarly, precipitation plays a complex role in shaping migration. For example, typhoon-induced floods in Vietnam triggered substantial internal migration (Berlemann and Tran, 2020), while increased rainfall in Ecuador actually reduced both internal and international migration (Gray, 2009). Beyond these direct impacts, climatic shocks that depress agricultural productivity and household incomes also affect migration flows, typically by constraining or reshaping migration decisions (Coniglio and Pesce, 2015; Cattaneo and Peri, 2016).

Climate change reduces agricultural production, heightening poverty and vulnerability (Cai et al., 2016; Cattaneo and Peri, 2016; Beine and Parsons, 2017). These pressures are intensified by extreme temperatures and recurrent droughts (Roberts et al., 2013), which can exacerbate poverty and contribute to conflict, thereby prompting migration and displacement (Koubi et al., 2016; Kelley et al., 2017; Selby et al., 2017; Chen and Mueller, 2019; Erdoğan and Cantürk, 2022). For instance, Kelley et al. (2015) identify climate change as a key factor behind the severe Syrian drought, which triggered agricultural collapse and economic instability, ultimately intensifying conflict and producing a large wave of refugees seeking asylum in neighboring countries and beyond. Such cases highlight the secondary effects of climate change-induced migration, including increased strain on host regions and heightened risks of social and cultural conflict (Barrios et al., 2006; Joseph and Wodon, 2013; Strobl and Valfort, 2015; Thiede et al., 2016; Dallmann and Millock, 2017; Ruiz et al., 2017; Gray et al., 2020; Zouabi, 2021). Migration also reshapes cultural proximity between home and host populations through compositional changes and cultural diffusion, which may foster assimilation but can equally generate tensions and conflict (Rapoport et al., 2020).

Studies covering the relationship between climate change and migration in Türkiye are very limited. Existing studies have primarily examined climate impacts and migration separately. On the climate side, Cebeci et al. (2019) analyzed the vulnerability of Turkish cities to drought, while reports from the Ministry of Climate and Environment (2021, 2022) documented nationwide effects of floods, wildfires, and droughts. Similarly, Özceylan and Coşkun (2012) and Benli et al. (2018) assessed the environmental and urban impacts of natural disasters, and Kiziroğlu (2017) explored urbanization dynamics in the context of climate change. On the migration side, Erdoğan and Cantürk (2022) studied migration from Afghanistan, Pakistan, and Bangladesh to Türkiye, employing the Foresight Model to project climate-induced student displacement. However, existing studies either focus on climate impacts or on migration separately, without systematically analyzing how climate variability influences Türkiye's internal migration patterns. This gap underscores the contribution of our study.

3 Overview of Türkiye

Türkiye, situated between 36° and 42° north latitude and 26° and 45° east longitude, lies at the crossroads of Europe and Asia, exposing it to diverse climatic, geographic, and socio-economic conditions that make it particularly sensitive to the impacts of climate change. With a population of approximately 86 million and a relatively young median age of about 32 years, the country is highly urbanized, as nearly 75% of people reside in metropolitan areas such as Istanbul, Ankara, and Izmir, largely driven by rural to urban migration in search of employment, education, and improved living standards. Rural areas, however, remain dependent on agriculture and livestock, increasing their vulnerability to drought and extreme weather events. In addition, Türkiye hosts nearly 5 million refugees, of whom approximately 3.5 million are from Syria, reflecting its central role in regional migration dynamics.⁷

Türkiye's geography features sharp contrasts in topography and climate over relatively short distances, producing substantial regional disparities in socio-economic conditions. The country experiences three dominant climate types: Mediterranean in the southwest, Black Sea in the north, and Continental across the

⁷Official statistics available at: <https://en.goc.gov.tr/>

interior and eastern regions. Much of the Black Sea, Mediterranean, and Eastern Anatolia regions is mountainous, with east–west ranges reaching considerable elevations. This geographic configuration generates strong variations in climate, livelihoods, and lifestyles across the country (Tekin, 2023).

Türkiye is part of the Mediterranean Basin, one of the regions most vulnerable to climate change. Since the 1980s, the country has experienced notable shifts in temperature and precipitation, with a clear trend toward a warmer and drier climate (Türkeş and Tatlı, 2009; Türkeş, 2012; Türkeş, 2017). Climate projections indicate that these patterns will intensify in the coming decades (Bayram and Öztürk, 2021; Bozkurt and Sen, 2013; Demircan et al., 2017). Türkiye’s precipitation climatology is strongly shaped by the North Atlantic Oscillation (NAO): positive phases of the NAO are linked to severe droughts, while negative phases bring increased rainfall (Türkeş and Erlat, 2005). With climate change, the positive intensity of this oscillation—and thus the risk of drought in Türkiye—is expected to rise (Visbeck et al., 2001).

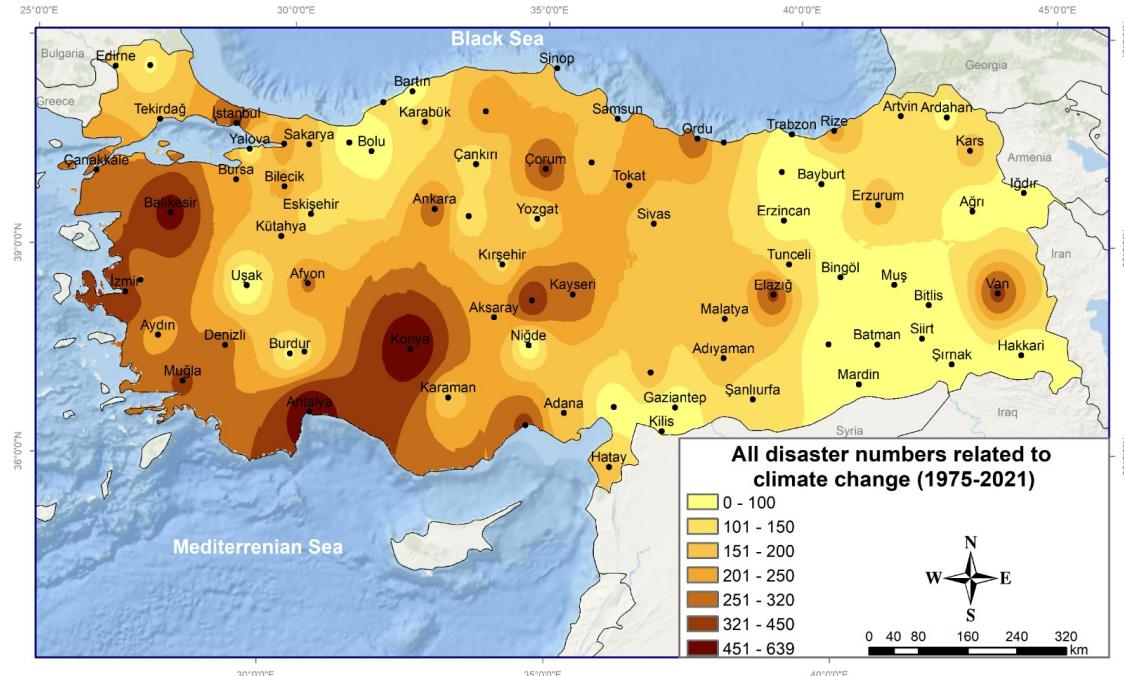


Figure 2: Total Climate Events in Türkiye from 1975 to 2021

Note: The figure shows the total number of climate-related disaster events, including droughts, extreme temperatures, heatwaves, floods, wildfires, and storms.

Data Source: Tekin (2023)

Across Türkiye, climate-related events have become increasingly evident in recent decades. Figure 2 illustrates the frequency of such events between 1975 and 2021.⁸ The southern regions appear particularly affected, reflecting both their geographic vulnerability to extreme weather and their concentration of major urban and economic centers. The visualization highlights the regional distribution of disasters, including droughts, extreme temperatures, heatwaves, floods, wildfires, and storms, with darker shades indicating higher frequencies of events.

Drought is poised to be one of the most significant climatic disasters shaping Türkiye’s future (Tekin, 2023). Besides the Black Sea region, drought conditions are expected to intensify mainly in the Central Anatolia, Southeastern Anatolia, and Mediterranean regions. Current data indicate that a significant portion of Türkiye’s land is at risk of drought and desertification (Türkeş, 2017; Bayram and Öztürk, 2021; Serkendiz et al., 2023). This situation threatens the primary livelihoods of rural populations, such as agriculture and livestock, potentially leading to increased migration.

⁸This figure reports only the number of recorded events and does not capture their intensity or consequences. Despite this limitation, it provides the most illustrative overview currently available.

Türkiye's position at the intersection of mid-latitude/polar and tropical-origin pressure systems leads to a variety of sub-climates. These physical and human factors contribute to high human mobility, making Türkiye one of the countries with the highest mobility rates globally. Historically, Türkiye has been a crucial transit route for migration. Many individuals from the Middle East and South Asia, such as Afghans, Iranians, Iraqis, Syrians, and Pakistanis, use Türkiye as a transit point to migrate to Europe. Recent years have seen an increase in natural disasters in these politically and economically turbulent regions. It is highly likely that Türkiye will continue to receive migrants from the Middle East and Western Asia, affected by drought and related issues, and from Southeast Asia, impacted by severe and irregular rainfall. Consequently, Türkiye is expected to face climate migrants from neighboring countries, as well as from Southeast Asia and Africa (Tekin, 2023). Studies indicate that many countries near Türkiye are at significant risk of food insecurity, heavily reliant on climate dependent livelihoods (Krishnamurthy et al., 2014). As climate change intensifies in these regions, it will likely trigger further migration.

4 Methodology

In this study, we use both the Gravity Model and the Random Utility Model to analyze the factors influencing migration. The Gravity Model in Economics was originally developed by (Tinbergen, 1962), then by (McCallum, 1995; Anderson and Van Wincoop, 2003) and then by (Rappaport, 2009) to explain international trade patterns and started to being used in labor and migration flows. Anderson (2013) adapted the Gravity Model from trade studies to migration. Afifi and Warner (2008); Bohra-Mishra et al. (2014); Backhaus et al. (2015); Beine and Parsons (2017) also used this model to analyze migration dynamics, taking into account geographic proximity, economic disparities, and the specific impact of climate variables like temperature and precipitation. The RUM establishes a mathematical framework to determine the factors influencing an individual's decision to migrate between cities within a country, assessing the utility of both the origin and destination cities based on current and expected future conditions (Beine and Parsons, 2015; Coniglio and Pesce, 2015; Beine and Parsons, 2017; Ruiz et al., 2017; Lewis and Swannell, 2018; Freeman and Lewis, 2021).

4.1 Random Utility Model

In this section, we establish a mathematical model using RUM (Beine et al., 2011; Beine and Parsons, 2017; Ruiz et al., 2017; Lewis and Swannell, 2018; Freeman and Lewis, 2021) to determine the conditions under which an individual decides to migrate from one city to another within a country. The RUM evaluates the utility derived from residing in the origin and destination cities, considering current utility and expected future conditions.

To define the utility function, we incorporate several factors that influence an individual's decision to migrate, broadly categorized as *push* and *pull* factors. As noted by Ravenstein (1889), people migrate to improve their circumstances, driven by social, political, and environmental conditions. Push factors are unfavorable conditions in the origin location, such as high living costs, adverse climate conditions, or limited economic opportunities, while pull factors refer to attractive features of the destination, such as better employment opportunities, favorable climate conditions, and lower living costs (Rummukainen, 2012).⁹ Within this framework, Afifi and Warner (2008) emphasized that hunger, war, and violations of human rights function as *extreme push factors* leading to forced migration. Similarly, Burzyński et al. (2022) identified real wages, education levels, and migration costs as determinants that can either push individuals away from the origin or pull them toward a destination. Individual risk preferences also shape these dynamics: Becker (1962) argued that “risk-lovers” are more likely to migrate than “risk-averse” individuals, thereby amplifying the pull of potential opportunities. Finally, Rapoport et al. (2020) noted that migration entails not only economic push and pull forces but also cultural ones, as individuals weigh both the loss of familiar environments and the potential cultural opportunities offered by the destination.

An individual decides to migrate from origin i to destination j if the expected utility in the destination city exceeds the current utility in the origin city, as shown in equation (1). We prefer to use expectations for

⁹Migration decisions are influenced by a wide range of factors, including demographic trends, policy interventions, and personal circumstances. For tractability, however, we restrict our model to the most widely studied and quantifiable determinants: economic, climatic, and social push and pull factors.

the next period while modeling our function, following the approach of (Reuveny and Moore, 2009; Coniglio and Pesce, 2015), who utilized expected values in their model. However, Cattaneo and Peri (2016); Beine and Parsons (2017) employed a two-period model with U_{jt+1} for the next period, solving their models over two periods. Additionally, Rappaport (2009) modeled dynamic and steady-state levels over all periods. In addition, we do not consider interest rates and discount rates as Reuveny and Moore (2009) used in their model.

$$U_{it} < U_{jt}^e \quad (1)$$

The utility in origin city i at time t , U_{it} , is influenced by several factors, including income, private benefits such as family ties or attachment to the origin city, daily living costs, and climate change-related costs such as extreme temperatures and droughts.

First, let us express the utility function in general terms for the origin city in equation (2):

$$U_{it}(I_{it}, B_{it}, C_{it}) = I_{it} + B_{it} - C_{it} + \epsilon_{it} \quad (2)$$

where I_{it} represents the income, B_{it} denotes the non-income (non-pecuniary) benefits of residing in the origin city, such as family ties, social networks, or attachment to place, and C_{it} indicates the costs associated with residing in the origin city. Finally, ϵ_{it} represents the unobserved (idiosyncratic) component of utility, capturing individual-specific preferences and factors not directly measurable within the model.

Next, let us define the components I_{it} , B_{it} , and C_{it} of U_{it} :

Income in the origin city is given by:

$$I_{it} = W_{it} + PI_{it} \quad (3)$$

where W_{it} denotes wealth, including assets such as houses, and PI_{it} represents permanent income, such as salary or wages.¹⁰ Beine et al. (2011) mentioned wages as income, but in our model, we prefer to use personal income.

Benefit in the origin city is given by:

$$B_{it} = PB_{it} \quad (4)$$

where PB_{it} denotes personal benefits such as family ties, friendships, habits, and attachments to the local area. We assume that the individuals in the origin city are risk-averse and homophilic (Rapoport et al., 2020), preferring not to change their location or social circle; thus, B_{it} is an increasing function. As observed in Turkish culture, people often have a strong attachment to their place of residence and lifestyle.

Costs in the origin city is given by:

$$C_{it} = DC_{it} + RB_{it} + CCC_{it} \quad (5)$$

where DC_{it} denotes daily costs which is the costs for living, RB represents refugee burden, and CCC_{it} denotes climate change costs. Beine and Parsons (2017) put their model climate change as a non-pecuniary cost. Given the focus of this paper on the impact of climate change, CCC_{it} can be further defined as:

$$CCC_{it} = T_{it} - P_{it} \quad (6)$$

where T_{it} represents the temperature and P_{it} denotes precipitation in the origin city i at time t . Temperature is an increasing function beyond a certain threshold, and we assume that an increase in temperature incurs additional costs with extreme heat being detrimental. Conversely, precipitation has a cost-saving effect, which can be beneficial against droughts but may also lead to negative utility in certain regions of Türkiye since too much rain is not desirable.

Thus, we can rewrite the utility function for the origin as in equation (7):

$$U_{it} = W_{it} + PI_{it} + PB_{it} - DC_{it} - RB_{it} - T_{it} + P_{it} \quad (7)$$

¹⁰This concept is derived from John Maynard Keynes' hypothesis on the Permanent Income Theory, which classifies income into wealth and permanent income. We assume people who decide to move have only one house as wealth and cannot sell or rent this house because of family heritage.

According to (7), the utility of a person in the origin city generally depends on wealth, personal income, personal benefits from living in the origin city, the presence of refugees, and the impact of temperature and precipitation.

In the case of Türkiye, an increase in temperature, especially during the summer, will lead people to migrate. Bohra-Mishra et al. (2014) stated that temperature has a nonlinear effect with a threshold where the average monthly temperature above 25°C significantly impacts migration decisions. Burzyński et al. (2022) noted that 25°C leads to lower productivity. Burke et al. (2015) suggested a threshold between 20°C and 30°C for migration. Given the occurrence of extreme temperatures in Türkiye especially in summer, living in those areas becomes costly, prompting people to relocate. An increase in precipitation is beneficial for individuals, especially those in the origin city engaged in agriculture. Barrios et al. (2006) modeled the relationship between agricultural production and precipitation. In addition, there are more than 5 million refugees living in Türkiye, a situation that has persisted for a long time. In some cities, the local population is very unsatisfied with this situation. The presence of these refugees creates negative externalities in terms of education and health services. Therefore, we include refugee burden in our model as a parameter in the cost function.

Similarly, expected the utility in the destination j at time t , U_{jt}^e , is influenced by many factors such as income, better climate conditions, migration costs from the origin to the destination, daily costs of living in the destination, and positive factors such as new opportunities and better expectations or hopes.

First, let us express the utility function for the destination city as expected values:

$$U_{jt}^e(I_{jt}, B_{jt}, C_{jt}) = I_{jt}^e + B_{jt}^e - C_{jt}^e + \epsilon_{jt} \quad (8)$$

where ϵ_{jt} represents the unobserved (idiosyncratic) component of utility, capturing individual-specific preferences and factors not directly measurable within the model.

Next, let us define the components of U_{jt}^e :

Income in the destination city is given by:

$$I_{jt}^e = PI_{jt}^e \quad (9)$$

where PI_{jt}^e is the expected personal income in destination city j at time t . We did not put wealth in equation (9) because we assumed that a person who lives in the origin city can not sell or rent his house because of heritage issues.

Benefits in the destination city are defined as:

$$B_{jt}^e = BCC_{jt}^e + BH_{jt}^e \quad (10)$$

where BCC_{jt}^e represents better climate conditions in destination city j at time t , BH_{jt}^e represents expected benefits of quality of life as (Rappaport, 2009) discussed. Also, if a person is a risk-lover, he will expect more benefits from migration (Becker, 1962).

Costs in the destination city are expressed as:

$$C_{jt}^e = MC_{ij}^e + D_{ij} + DC_{jt}^e \quad (11)$$

where MC_{ij}^e is the migration cost from origin city i to destination city j , D_{ij} is the distance between origin city i and destination city j , and DC_{jt}^e is the daily cost of living in destination city j at time t . We prefer to use travel costs as distance and think the cost is 1 unit per distance. Anderson (2013); Santana-Gallego and Paniagua (2022) mentioned the iceberg cost, but we prefer to use migration cost.

By combining the expected values of the functions, the destination's utility function is written as follows:

$$U_{jt}^e = PI_{jt}^e + BCC_{jt}^e + BH_{jt}^e - MC_{ij}^e - D_{ij} - DC_{jt}^e \quad (12)$$

Equation (12) indicates that the utility of a person considering migration depends on the expected personal income in the destination city, better climate conditions, benefits of hope possibly as being risk-lover, migration cost, distance (which is directly considered as a cost), and daily cost.

So, the decision to migrate can be expressed as:

$$W_{it} + PI_{it} + PB_{it} - DC_{it} - RB_{it} - T_{it} + P_{it} < PI_{jt}^e + BCC_{jt}^e + BH_{jt}^e - MC_{ij}^e - D_{ij} - DC_{jt}^e \quad (13)$$

For simplicity, we assume PI_{it} and PI_{jt}^e are equal; DC_{it} and DC_{jt}^e are equal; PB_{it} and BH_{jt}^e are equal. The new equation will be:

$$W_{it} + PB_{it} - RB_{it} - T_{it} + P_{it} < BCC_{jt}^e - MC_{ij}^e - D_{ij} \quad (14)$$

Equation (14) captures the essential elements influencing an individual's migration decision by comparing the utility derived from the factors in both the origin and destination cities. Specifically, it shows that if the total utility of a person in the origin city exceeds that in the destination city, the person will be inclined to migrate.

According to equation (14), we can conclude that climate change will affect personal preferences. If the temperature increases, people seek new places in response to the hot temperatures. We did not include temperature as a cost in the destination city since individuals migrate with the expectation of better climate conditions and favorable weather, as suggested by Rappaport (2009). Additionally, we considered the refugee burden as a cost since the capacity of a place depends on the number of people. Refugee burden also causes conflicts in cultural aspects, resulting in negative externalities and increased costs for the local population.

Let's proceed to calculate the migration probability function. The probability that $U_{jt}^e > U_{it}$ can be represented using an exponential function.

$$P(U_{jt}^e > U_{it}) = \min \left(1, \frac{e^{U_{jt}^e}}{e^{U_{it}}} \right) \quad (15)$$

Substituting the utility functions, we get:

$$P(U_{jt}^e > U_{it}) = \min \left(1, \frac{e^{BCC_{jt}^e - TMC_{ij}^e - D_{ij}}}{e^{W_{it} + PB_{it} - RB_{it} - T_{it} + P_{it}}} \right) \quad (16)$$

Now, let's consider the probability of choosing a particular destination j among all possible destinations j . Assuming there are multiple possible destinations, the individual will choose the destination that maximizes his utility. The probability of choosing destination j out of all possible destinations j is given by:

$$P(\text{Choose } j \mid \text{Migration}) = \frac{e^{U_{jt}^e}}{\sum_{k \in J} e^{U_{kt}^e}} \quad (17)$$

We can combine the equations (16) and (17) and get equation (18) :

Combining these two steps, the overall probability of migrating from origin i to destination j is:

$$P(\text{Migration to } j) = \min \left(1, \frac{e^{BCC_{jt}^e - TMC_{ij}^e - D_{ij}}}{e^{W_{it} + PB_{it} - RB_{it} - T_{it} + P_{it}}} \right) \cdot \left(\frac{e^{BCC_{jt}^e - TMC_{ij}^e - D_{ij}}}{\sum_{k \in J} e^{BCC_{kt}^e - TMC_{ik}^e - D_{ik}^e}} \right) \quad (18)$$

The equation (18) tells us that the decision of a person for migration depends on two main components. First, the expected utility in the destination city should be higher than the current utility in the origin city. Second, among all possible destination options, the individual will choose the one that offers the highest probability of better utility. Thus, the highest probability destination will be selected for migration.

According to Equation (18), migration from an origin to a destination city is primarily influenced by factors such as temperature, precipitation, distance, income, and migration cost. If the temperature increases, precipitation decreases, distance increases, migration cost increases, and income decreases, the probability of migration will decrease. Conversely, if the temperature decreases, precipitation increases, distance decreases, migration cost decreases, and income increases, the probability of migration will increase.

we can rewrite the equation as:

$$M_{ijt} = \frac{e^{BCC_{jt}^e - TMC_{ij}^e - D_{ij}}}{e^{W_{it} + PB_{it} - RB_{it} - T_{it} + P_{it}}} \cdot \eta_{ijt} \quad (19)$$

where η_{ijt} represents the unobserved (idiosyncratic) component of utility, capturing individual-specific preferences and factors not directly measurable within the model.

4.2 Gravity Model

The gravity model aims to formalize and predict the geography of flows or interactions.¹¹ It is commonly employed to predict trade flows, but recently it has also been applied to migration trends.(Anderson and Van Wincoop, 2003; Afifi and Warner, 2008; Beine et al., 2011; Beine and Parsons, 2017; Grohmann, 2023).

The gravity model of international trade is a foundational tool in economics for analyzing trade flows between countries. The basic form of the gravity model posits that trade between two countries is proportional to the product of their economic sizes (typically GDP) and inversely proportional to the distance between them.

The simplest form of the gravity equation, as introduced by Tinbergen (1962) and widely used by (McCallum, 1995; Anderson and Van Wincoop, 2003; Silva and Tenreyro, 2006; Anderson, 2013; Rapoport et al., 2020), can be expressed as:

$$T_{ij} = \alpha \frac{Y_i Y_j}{D_{ij}} \quad (20)$$

where T_{ij} is the trade flow from country i to country j , Y_i and Y_j are the GDPs of countries i and j , respectively, D_{ij} is the distance between the two countries, and α is a constant.

McCallum (1995) used this model to illustrate the significant impact of national borders on trade, famously showing that Canadian provinces trade more with each other than with U.S. states, even when controlling for distance and economic size.

Anderson and Van Wincoop (2003) refined the model by introducing multilateral resistance terms to account for the fact that trade between two countries depends not only on their bilateral barriers but also on their trade barriers with other countries. The modified equation is:

$$T_{ij} = \frac{Y_i Y_j}{Y_w} \left(\frac{t_{ij}}{P_i P_j} \right)^{1-\sigma} \quad (21)$$

where Y_w is the world GDP, t_{ij} is the bilateral trade cost between countries i and j , P_i and P_j are the multilateral resistance terms, and σ is the elasticity of substitution. This framework highlights the importance of considering the relative resistance to trade, not just the bilateral distance.

Silva and Tenreyro (2006) addressed the issue of zero trade flows, which pose a problem for log-linearized models. They proposed using PPML estimator to handle zero trade values and heteroskedasticity. Then the model becomes:

$$E[T_{ij}] = \exp(\beta_0 + \beta_1 \ln Y_i + \beta_2 \ln Y_j + \beta_3 \ln D_{ij} + \mathbf{X}'_{ij} \boldsymbol{\beta}) \quad (22)$$

where \mathbf{X}_{ij} represents additional independent control variables.

Rappaport (2009); Santana-Gallego and Paniagua (2022) extended the gravity model by incorporating additional variables that influence trade, such as common language, colonial history, and regional trade agreements. The extended model is:

$$T_{ij} = \alpha \left(\frac{Y_i^{\beta_1} Y_j^{\beta_2}}{D_{ij}^{\beta_3}} \right) \exp(\gamma_1 \text{Lang}_{ij} + \gamma_2 \text{Col}_{ij} + \gamma_3 \text{RTA}_{ij} + u_{ij}) \quad (23)$$

where Lang_{ij} is a dummy variable for common language, Col_{ij} is a dummy variable for colonial ties, RTA_{ij} is a dummy variable for regional trade agreements, and u_{ij} is an error term (Orefice, 2015).

Combining insights from Anderson (2013) and Silva and Tenreyro (2006), we can present the gravity model in a functional form that addresses heteroskedasticity and non-linearity:

$$T_{ij} = \alpha Y_i^{\beta_1} Y_j^{\beta_2} D_{ij}^{\beta_3} \exp(\gamma \mathbf{Z}'_{ij} \boldsymbol{\epsilon}_{ij}) \quad (24)$$

where \mathbf{Z}_{ij} includes all additional explanatory variables, and $\boldsymbol{\epsilon}_{ij}$ represents the unobserved (idiosyncratic) component of trade flows, capturing individual-specific preferences and factors not directly measurable within the model.

¹¹The law posits that the attractive force between two objects i and j is given by: $F = G \frac{M_i \times M_j}{D_{ij}^2}$, where F represents the attraction force, M_i and M_j are the respective masses of the objects, D_{ij} is the distance between them, and G is the gravitational constant, which depends on the units of measurement for mass and force.

In the context of migration, the same functional form can be adapted by replacing trade flows with migration flows and explicitly incorporating economic and climatic variables as the main determinants. Thus, the gravity equation becomes:

$$M_{ij} = \alpha GDP_i^{\beta_1} GDP_j^{\beta_2} D_{ij}^{\beta_3} \exp(\gamma_1 Temp_i + \gamma_2 Temp_j + \gamma_3 Prec_i + \gamma_4 Prec_j + \gamma_5 RB_i) \epsilon_{ij} \quad (25)$$

where M_{ij} is the migration flow from origin i to destination j , GDP_i and GDP_j represent the economic size of the origin and destination, D_{ij} is the distance between them, $Temp_i$ and $Temp_j$ are the average temperatures, $Prec_i$ and $Prec_j$ are the levels of precipitation, and RB_i denotes the refugee burden at the origin. ϵ_{ij} represents the unobserved component of migration, capturing individual-specific preferences and factors not directly measurable within the model.

4.3 Econometric Specification

The estimation model integrates RUM and the Gravity Model to capture the determinants of migration flows. This combined approach leverages the microeconomic foundation of the RUM, which explains individual migration decisions based on utility maximization, and the structural perspective of the Gravity Model, which situates these decisions within broader economic and geographical contexts.

RUM provides a basis for understanding migration decisions, positing that individuals migrate if the expected utility from the destination city exceeds that of the origin city, influenced by factors like income, climate, and living costs. The Gravity Model, widely used in trade economics and refined by Tinbergen (1962) and Anderson and Van Wincoop (2003), posits that interactions between locations are proportional to their economic sizes and inversely proportional to their distance. Combining RUM's detailed individual-level insights with the Gravity Model is useful in our context where migration is influenced by temperature, precipitation, and GDP levels.

Estimating our model involves utilizing the models of (Backhaus et al., 2015; Beine and Parsons, 2015, 2017; Ruiz et al., 2017). Combining equations (19) and (24) yields in equation (26).

$$\begin{aligned} \ln(M_{ijt}) = & \alpha + \beta_1 \ln(T_{it}) + \beta_2 \ln(T_{jt}) + \beta_3 \ln(P_{it}) + \beta_4 \ln(P_{jt}) \\ & + \beta_5 \ln(GDP_{it}) + \beta_6 \ln(GDP_{jt}) + \beta_7 \ln(D_{ij}) + \beta_8 \ln(RB_{it}) \\ & + \lambda_i + \delta_t + \theta_j + \epsilon_{ijt} \end{aligned} \quad (26)$$

where M_{ijt} is the migration flow from origin i to destination j at time t . T_{it} and T_{jt} are the temperatures of the origin and destination at time t , respectively. P_{it} and P_{jt} are the precipitation levels of the origin and destination at time t , respectively. GDP_{it} and GDP_{jt} are the GDPs of the origin and destination, respectively. D_{ij} is the distance between the origin and destination. RB_{it} is the refugee burden at the origin at time t . α is the constant term. $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8$ are the coefficients for each variable. λ_i is the origin fixed effect. δ_t is the time fixed effect. θ_j is the destination fixed effect, ϵ_{ijt} is the error term with i.i.d.

For parsimony, we can refine the equation (26) and get (27)

$$\ln(M_{ijt}) = \beta_0 + \beta_i \ln(X_{it}) + \beta_j \ln(X_{jt}) + \beta_{ij} \ln(D_{ij}) + \lambda_i + \delta_t + \theta_j + \epsilon_{ijt} \quad (27)$$

where X_{it} represents the variables belonging to the origin city; X_{jt} represents the variables belonging to the destination city.

4.4 Estimation Method

To estimate our migration model, we employ three complementary approaches. First, we use pooled OLS as a baseline specification, providing a straightforward benchmark for comparison. Second, we apply PPML estimator, which is widely regarded as the most reliable method for gravity-type models because it accounts for zero flows and heteroskedasticity. Finally, we implement HT estimator to address endogeneity and unobserved heterogeneity, particularly in relation to time-invariant variables such as distance. Together, these methods ensure that our results are both robust and comparable across different estimation techniques.

We use the PPML method to estimate our model and then employ the Hausman-Taylor estimator to tackle endogeneity issues. Additionally, we offer results obtained using pooled OLS for the validity of our data.

4.4.1 Pooled OLS Method

We first estimate the model using pooled OLS, which combines cross-sectional and time-series observations into a single regression framework. This approach provides a simple baseline against which more advanced estimators can be compared.

Pooled OLS assumes that the relationship between the dependent and independent variables is constant across time and units, thereby ignoring unobserved heterogeneity. While this limitation can bias estimates, pooled OLS remains useful as a benchmark to assess the robustness of our results (Wooldridge, 2010).

By including pooled OLS results, we ensure that our findings are not model-specific and validate the robustness of our data and conclusions. This approach helps demonstrate the reliability of our estimates and provides a comprehensive understanding of the impact of various factors on migration flows.

4.4.2 Poisson Pseudo-Maximum Likelihood Method

We estimate the model using PPML estimator, too. Silva and Tenreyro (2006) show that PPML provides consistent estimates for gravity models, even when the dependent variable contains zero values, a common feature of migration data.

PPML estimates the dependent variable in its original scale, treating it as a count variable. This avoids issues arising from log transformations, allows for zero flows, and produces unbiased elasticity estimates in the presence of heteroscedasticity (Silva and Tenreyro, 2011; Linders and De Groot, 2006).

The method has been widely applied in migration research (Beine et al., 2016; Beine and Parsons, 2017). For example, Ruiz et al. (2017) applied PPML to study the effect of climatic shocks on internal migration in Mexico, demonstrating its suitability for analyzing migration flows.

4.4.3 Hausman-Taylor Method

We also apply HT estimator to address endogeneity and unobserved heterogeneity in the migration model. Traditional fixed effects models control for unobserved heterogeneity but cannot estimate coefficients for time-invariant variables such as distance. Random effects models allow for time-invariant regressors but yield biased estimates when regressors are correlated with individual-specific effects. The HT approach overcomes these issues by decomposing the error term into individual-specific and idiosyncratic components, using a mixed-effects framework to address endogeneity (Hausman and Taylor, 1981; Wooldridge, 2010).

The HT estimator provides consistent estimates for both time-varying and time-invariant variables by exploiting variation within and between entities (Wooldridge, 2010). This makes it suitable for migration studies, where variables such as distance remain constant while others vary over time.

Empirical applications confirm its effectiveness. Egger and Pfaffermayr (2004) showed that the HT model addresses endogeneity in trade and FDI analysis, while Serlenga and Shin (2004) extended it to account for unobserved time-specific factors. Baltagi et al. (2003) demonstrated that the HT estimator exploits within and between variations of strictly exogenous variables as instruments, allowing consistent estimation when regressors correlate with individual effects. In this study, we apply the HT model to migration flows, providing one of the first applications of this method in this context.

5 Data

In this section, we describe the origin and destination cities used in our analysis of internal migration in Türkiye. Administratively, Türkiye is divided into 81 provinces (*iller*), which are commonly referred to as cities in official statistics and form the basis of our dataset.¹² From these, we selected 30 provinces as origins and 80 provinces as potential destinations.

The choice of origin provinces was guided primarily by climate related factors, including the frequency of droughts, extreme heat, wildfires, and floods. Provinces that exceeded certain threshold levels in these

¹²In Türkiye, the administrative unit officially called a “province” (*il*) is often translated into English as a “city.” Each province contains many districts, towns, and villages, but in statistical and economic analyses, the province is treated as the unit of observation. Thus, when we refer to “cities” in this study, we mean provinces at the Nomenclature of Territorial Units for Statistics-3 (NUTS-3) level.

indicators, for example, based on the drought index, were designated as origins. This selection strategy ensures that the origins represent provinces most exposed to climate risks and therefore most likely to generate out-migration. The 80 destination provinces represent all remaining provinces that serve as potential migration targets.

The dataset covers the period from 2008 to 2022. With 30 origin provinces, 80 destination provinces, and 15 years, the dataset contains $30 \times 80 \times 15 = 36,000$ observations. In panel terms, this corresponds to $30 \times 80 = 2,400$ origin–destination province pairs observed over 15 years.

To illustrate the model's underlying principles, consider a simplified scenario with two origin cities (labeled A and B) and five destination cities (labeled A, B, C, D, E) as shown in Figure 3. In this model, cities A and B can send migrants to any of the destination cities, including those with the same label, except for the restriction against self-migration. Consequently, city A can send migrants to cities B, C, D, and E, but not to itself. Similarly, city B can send migrants to cities A, C, D, and E, adhering to the model's constraints against self-migration. This simplified schema in Figure 3 is expanded to the full scale of the study, where each of the 30 origin cities has potential migration paths to 80 other cities, excluding itself, out of the total 81 destinations.

Furthermore, we did not constrain origin cities from sending migrants to other origin cities. We conducted a unidirectional analysis from origin to destination, allowing migration from one city to another. This choice is shaped by Türkiye's unique characteristics, including its geographic, absolute, and climatic conditions. Typically, migration patterns in Türkiye follow a south-to-north¹³ and undeveloped-developed trajectory. However, individual preferences and expectations sometimes lead people to migrate to cities with similar conditions. Therefore, our analysis focuses on unidirectional migration.

¹³Beine and Parsons (2015) found significant differences in migration determinants to the global 'North' and 'South'. Migration to the North, driven by economic incentives like wage differentials, involves more skilled migrants, who are less influenced by network effects and environmental variables but more sensitive to wage ratios and common ethnic languages. Conversely, migrations to the South, characterized by shorter distances, are significantly influenced by shared borders but show no significant impact from wage differentials, linguistic roots, or international violence.

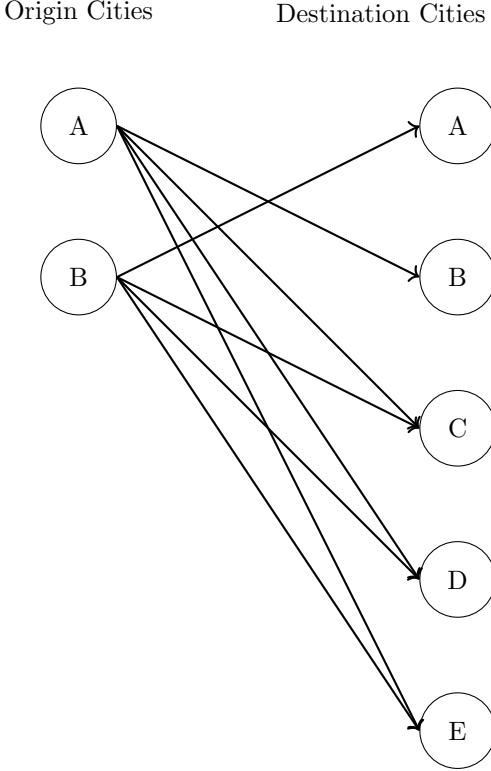


Figure 3: Summary Schema of Migration Routes from Origin Cities to Destination Cities

Note: To illustrate the principles of the migration model, a simplified representation is considered with two origin cities (A, B) and five destination cities (A, B, C, D, E), demonstrating the unidirectional flow and restriction against self-migration. This abstraction helps in understanding the potential migration paths within the country.

Figure 4 illustrates the criteria used to select origin cities. We selected cities based on climatic conditions such as droughts, wildfires, or floods, as well as their proximity to the equator and level of urbanization (Burzyński et al., 2022). The black shapes indicate the selected origin cities, yellow shapes indicate regions affected by droughts, blue shapes indicate regions affected by floods, and red shapes with a yellow interior indicate regions affected by wildfires. Droughts are observed across the entire country, floods are generally seen in the northern regions, and wildfires are mostly seen in the southern regions.

Table 1 presents the summary statistics for the variables used in our analysis, including the number of observations, mean values, standard deviations, and ranges. While some variables have a full sample of 36,000 observations, others contain fewer due to data availability. For example, refugee data is available only from 2014, following the establishment of the Republic of Türkiye's Ministry of Interior Presidency of Migration Management(RTMIPMM), while wildfire records have been collected since 2012. These differences account for the variation in observation numbers across variables.

Migration data were obtained from the Turkish Statistical Institute (TSI) Population Statistics Portal.¹⁵ Migration flows are reported from origin to destination provinces, and we organized the data by year and province. This process involved addressing issues related to the unique characters in Turkish alphabets, which sometimes caused discrepancies in the sorting order. Additionally, we encountered zero values for migration to some destination cities, which were carefully handled during the data cleaning process. Migration flows range from 0 to about 30,000 people.

Population data for both origin and destination provinces were collected from TSI.¹⁶ Within our sample, provincial populations range from roughly 75,000 in the smallest provinces to nearly 16 million in Istanbul, the country's largest city.

¹⁵Data source: <https://nip.tuik.gov.tr>

¹⁶Data Source: <https://data.tuik.gov.tr>

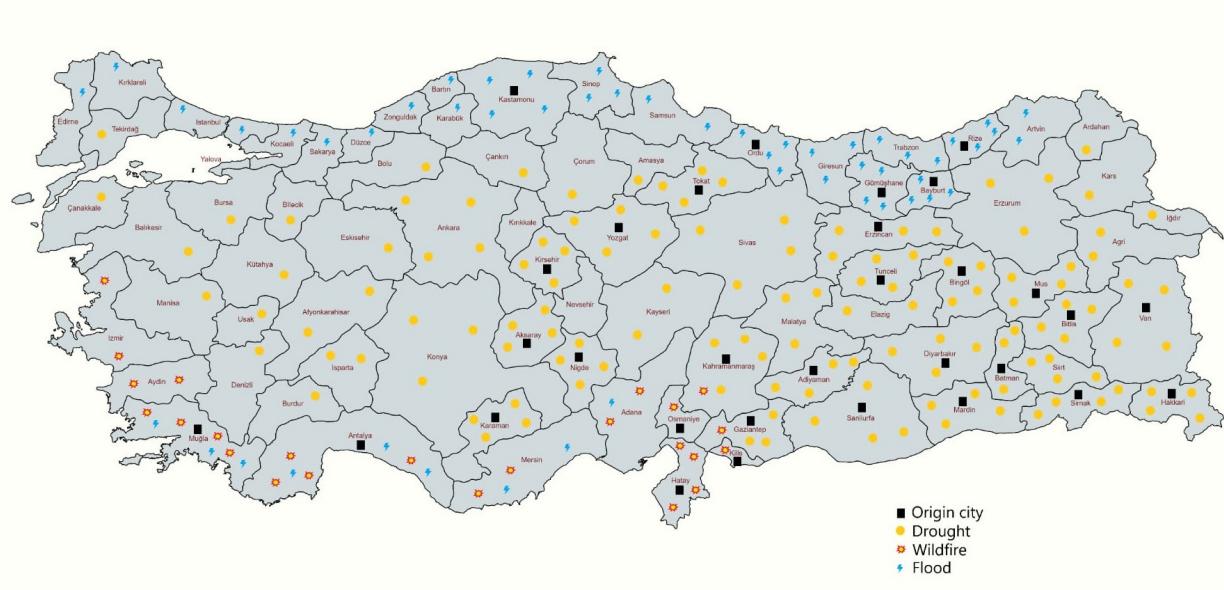


Figure 4: Selected Origin Cities for Migration¹⁴

Note: The Map belonging to Türkiye illustrates the criteria used to select origin cities. We categorized cities based on the dominant climatic factors affecting them, using observations and established indices. Specifically, we employed the Bagnouls-Gaussen aridity index to identify cities experiencing drought. Cities with a high Bagnouls-Gaussen index were categorized under 'city drought,' visually represented with yellow shapes. If floods were identified as the most severe climatic challenge, we categorized the city under 'city reason flood,' visually represented with blue shapes. Cities facing severe impacts from wildfires were categorized under 'wildfires,' and visually represented with red shapes with a yellow interior. Additionally, the black shapes indicate the selected origin cities. Droughts are observed across the entire country, floods are generally seen in the north, and wildfires are mostly seen in the south. Data Source: [TurkishMeteorologicalService/](https://www.TurkishMeteorologicalService/), [https://www.mapchart.net/turkiye.html/](https://www.mapchart.net/turkiye.html)

Distance data were taken from the Republic of Türkiye's General Directorate of Highways.¹⁷ Distances are measured along the road network rather than Euclidean (straight-line) distances. These measures are treated as time-invariant and therefore motivate the use of the Hausman–Taylor estimator in our econometric specification. Distances between provinces in our dataset range from about 45 km to just over 2,000 km.

Climatic variables were collected from the Turkish State Meteorological Service (TSMS).¹⁸ Monthly records of temperature and precipitation were averaged into annual values. Average temperatures in the dataset range from about 4°C in colder provinces to about 21°C in warmer ones, while precipitation varies between roughly 100 mm and 3,000 mm annually. Figure 5 illustrates long-term trends, showing a rise in average temperatures and a decline in precipitation since 1950, consistent with global findings (Beine and Parsons, 2017; Berlemann and Steinhardt, 2017). The variability of these measures has also increased, indicating climatic fluctuations.

¹⁷Data Source: <https://www.kgm.gov.tr/>

¹⁸Data Source: <https://www.mgm.gov.tr/eng>

Table 1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Migration Number	36,000	284.737	820.162	0	30,036
Origin City Population	36,000	702,668.25	587,214.54	74,412	2,688,004
Destination City Population	36,000	975,063.53	1,750,685.7	74,412	15,907,951
Distance (km)	36,000	757.159	379.163	45	2016
Origin City Temperature (°C)	36,000	14.087	3.651	4.4	20.7
Destination City Temperature (°C)	36,000	13.569	3.213	4.4	20.7
Origin City Precipitation (mm)	36,000	723.991	470.965	144.8	2974.8
Destiny City Precipitation (mm)	36,000	741.866	644.53	100.7	3044.7
Origin City GDP per capita (Dollar)	36,000	6592.078	2212.355	2907.293	14787.904
Destination City GDP per capita (Dollar)	36,000	8035.806	3027.751	2766.7	20882.711
Origin City Agriculture Products (Lira)	36,000	635,222.48	552,368.44	107,435.48	4,169,857.3
Origin City Electricity Consumption (KiloWatt)	36,000	1982.938	1217.849	443	8102
Origin City Unemployment Rate (%)	21,600	13.522	6.898	3.8	33.7
Number of Wildfires	21,040	39.213	65.649	0	322
Origin City Amount of Area Burnt (m^2)	21,040	571.794	4847.577	0	60,366.56
Origin City Number of Refugees	16,800	2340.048	7401.524	40	69,441
Law of Refugees in 2014 (Dummy Variable)	36,000	.533	.499	0	1

Note: The summary statistics show different numbers of observations across variables, with some reaching 36,000 while others have fewer. This variance is linked to the timing of data availability for specific variables. Refugee data, for example, has been gathered since 2014, corresponding to the establishment of the Republic of Türkiye's Ministry of Interior Presidency of Migration Management. Moreover, records of fire incidents have been accessible since 2012. These differing start dates for data collection account for the varied observation counts in the variables.

Data Source: TSI

We collected monthly temperature and precipitation data from the Turkish State Meteorological Service (TSMS).¹⁹ To convert the monthly records into annual data, we computed the mean for each year over all years. This methodological approach allowed us to examine temporal temperature and precipitation trends on an annual basis. While some researchers rely on annual average temperature (Beine and Parsons, 2015; Backhaus et al., 2015; Nordhaus and Boyer, 2000), others focus on anomalies and extreme values during winter and summer (Rappaport, 2009; Coniglio and Pesce, 2015; Burzyński et al., 2022).

Figure 5 illustrates the trends in temperature and precipitation between 1950 and 2022, with data normalized to the base year of 1950. Consistent with (Beine and Parsons, 2017; Berlemann and Steinhardt, 2017), our analysis reveals a clear trend of increasing average temperatures and decreasing average precipitation over the years. This pattern is also evident in the context of Türkiye, where we observed a notable rise in temperature values and a decline in precipitation levels across the studied period. Furthermore, the analysis indicates an increase in the variability of temperature and precipitation changes, suggesting climatic fluctuations over time. It is seen that anomalies of trend has increased over the years.

Economic variables were also drawn from TSI. Provincial GDP per capita (in U.S. dollars) ranges from approximately \$2,800 to over \$20,000. Data on agricultural production, originally reported in Turkish lira, were converted into real values by applying annual exchange rates to express figures in U.S. dollars. These values range from about 100,000 lira in the least productive provinces to over 4 million lira in the most productive.

Electricity consumption, measured in kilowatt-hours, varies from fewer than 500 to over 8,000. Labor market indicators include provincial unemployment rates, available from TSI. Rates range from about 4% to nearly 34% across provinces and years.

Environmental stress variables include wildfire data from the Ministry of Forest in Türkiye.²¹ The number of wildfire incidents varies from 0 to more than 300 annually, while the total burned area ranges from 0 to

¹⁹Data Source: <https://www.mgm.gov.tr/eng>

²⁰Data Source: <https://climateknowledgeportal.worldbank.org/>

²¹Data Source: <https://www.ogm.gov.tr/>

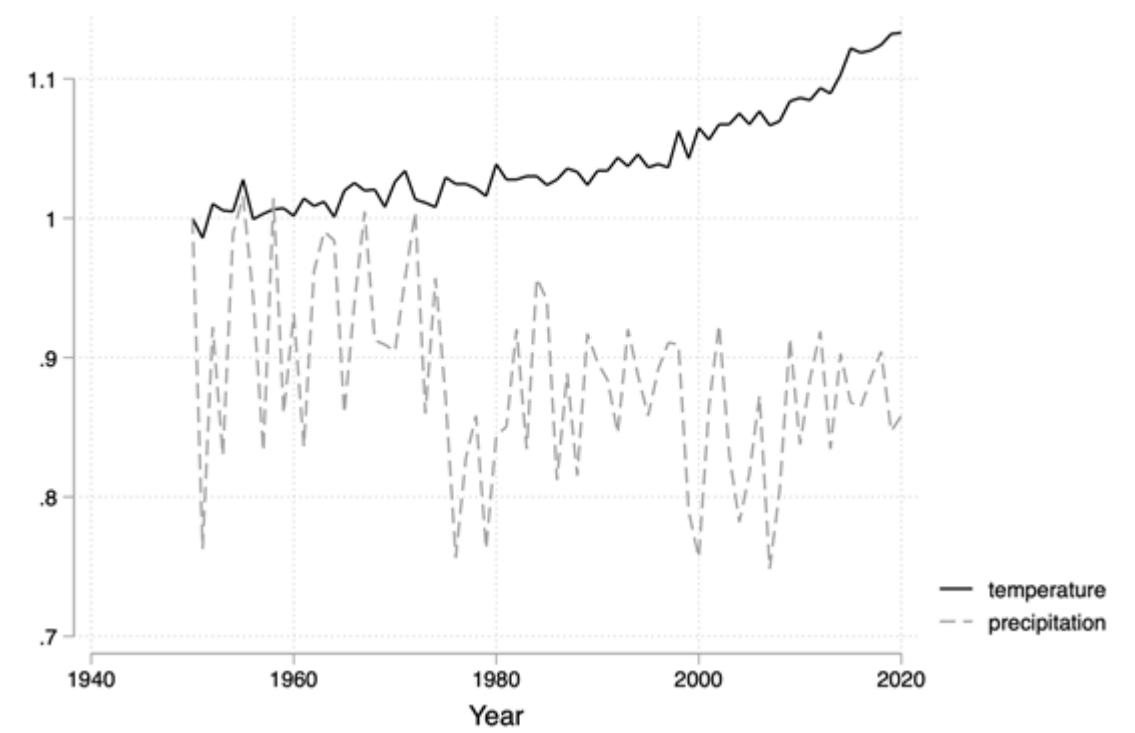


Figure 5: Temperature and Precipitation Changes in Türkiye from 1950 to 2022²⁰

Note: We normalized the data to 1950, assigning it a value of 1 to analyze trends in temperature and precipitation.

about 60,000 square meters.

Additionally, we gathered refugee data from the Türkiye Presidency of Migration. We include the refugee numbers as a crucial factor to evaluate the climate change secondary exposure impacts in Türkiye, particularly following the Syrian conflict. This is based on the understanding that the Syrian war and the resulting refugee inflow into Türkiye can be partly linked to climate-related issues (Kelley et al., 2017). In addition, we introduce a binary variable, law-dum, to indicate the enforcement of specific legal measures concerning refugees, especially Syrians, in Türkiye. This variable is assigned a value of 1 following the establishment of RTMIPMM in 2014, a key moment in the legal and administrative reaction to the refugee influx²². According to RTMIPMM, Türkiye currently shelters over 4 million Syrian refugees and more than 2 million individuals from other countries²³.

6 Identification Strategy

We begin our identification strategy with climatic variables, which form the primary focus of this study. We include temperature and precipitation for both origin and destination provinces to capture the push effects of adverse conditions at the origin and the pull effects of favorable conditions at the destination.

We then control for additional factors that influence migration decisions. We include GDP per capita at both origin and destination to reflect economic opportunities, the distance between provinces to proxy migration costs, and migration pressure variables such as the number of refugees in the origin and a post-2014 legal dummy that reflects institutional changes in migration policy.

For estimation, we rely primarily on PPML estimator. We use PPML because it accommodates zero

²²RTMIPMM established in 2014, plays a crucial role in managing migration and refugee affairs in Turkey. This institution's formation marked a significant policy shift aimed at better handling the influx of refugees and migration-related issues. Using 2014 as a dummy variable in our study helps to capture the effects of this policy change on internal migration dynamics.

²³Data Source: <https://en.goc.gov.tr/>

migration flows and corrects for heteroskedasticity, both of which are common in gravity-type migration models (Silva and Tenreyro, 2006). In addition, we apply the Hausman–Taylor (HT) estimator, which allows us to address endogeneity and to estimate the effects of both time varying and time-invariant variables, such as distance (Hausman and Taylor, 1981; Wooldridge, 2010). By combining these approaches, we ensure that the effects of climate on migration are identified while also accounting for economic, geographic, and institutional influences.

7 Results

Table 2 reports the pooled OLS estimates for the whole country sample. Origin temperature and precipitation are generally positive and statistically significant across specifications, suggesting that climatic conditions in origin cities play an important role in shaping migration flows. Economic conditions at the origin, measured by GDP per capita, are also positively associated with migration, indicating that higher income levels in sending regions do not necessarily deter mobility. At the destination, temperature shows a positive and significant relationship with migration, while precipitation effects are less consistent. Distance between origin and destination cities has the expected negative and significant effect, reflecting migration costs. Policy- and migration-related factors also matter: refugee presence and the post-2014 migration law are both positively associated with migration flows. Controlling for time, origin, and destination fixed effects strengthens the robustness of the estimates by accounting for unobserved factors that vary across cities and over time.

This section reports the estimation results obtained from pooled OLS, Poisson Pseudo-Maximum Likelihood, and Hausman–Taylor methods. We present results for two samples: (i) the full sample set of provinces in Türkiye, and (ii) a subsample restricted to provinces most affected by drought. The consistency of the findings across the three estimation methods highlights the robustness of our results. For clarity, we first present the estimates for the full sample, followed by those for the drought-affected subsample.

7.1 Whole Country Sample of Türkiye

In this subsection, we present the results for the whole sample used in our analysis, which covers 30 origin cities, 80 destination cities, and 15 years, yielding a total of 36,000 observations.

Table 2: Whole Country Sample of Türkiye Pooled OLS Results

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Log origin temperature	1.392*** (0.038)	0.425*** (0.075)	0.423*** (0.0074)	0.429*** (0.074)	0.989*** (0.049)	0.419*** (0.0074)	0.279*** (0.054)	0.419*** (0.074)
Log origin precipitation	0.076*** (0.008)	0.079*** (0.011)	0.086*** (0.011)	0.085*** (0.010)	0.066*** (0.009)	0.084*** (0.011)	-0.095*** (0.009)	0.084*** (0.011)
Log origin GDP per capita			0.315*** (0.040)	0.315*** (0.039)	0.315*** (0.034)	0.320*** (0.040)	-0.029 (0.034)	0.320*** (0.040)
Log destination temperature				0.820*** (0.063)	0.975*** (0.052)	0.860*** (0.059)	0.487*** (0.051)	0.860*** (0.059)
Log destination precipitation				-0.016 (0.010)	0.002 (0.009)	-0.009 (0.010)	-0.097*** (0.013)	-0.009 (0.010)
Log destination GDP per capita					0.114*** (0.043)	0.011 (0.037)	0.392*** (0.045)	0.214*** (0.038)
Log distance						-0.733*** (0.039)	-0.895*** (0.031)	-0.747*** (0.038)
Log number of refugee							0.112*** (0.005)	-0.895*** (0.031)
Law-dummy								0.466*** (0.012)
Constant	0.433*** (0.130)	2.387*** (0.271)	-0.267 (0.454)	-1.917*** (0.629)	0.923*** (0.359)	0.922** (0.623)	6.392*** (0.434)	0.922** (0.623)
Year FE	No	Yes	Yes	Yes	No	Yes	No	Yes
Origin FE	No	Yes	Yes	Yes	No	Yes	No	Yes
Destination FE	No	No	No	Yes	No	Yes	No	Yes
Observations	36000	36000	36000	36000	36000	36000	16800	36000
R-squared	0.046	0.262	0.262	0.449	0.226	0.629	0.256	0.628
Wald chi2	1336.75	6373.14	6469.01	8094.06	2442.88	11403.43	1391.11	11403.43

Note: All dependent and independent variables are analyzed in logarithmic form except for the law dummy since it is a dummy variable using pooled OLS. We added control variables to the model and checked for time-fixed, origin-fixed, and destination-fixed effects. We checked for destination-fixed effects after Model 4, which includes the control variables related to destination cities. Robust standard errors are in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2 reports results from eight pooled OLS models that examine internal migration flows across Türkiye. The models are structured progressively to test the stability of key variables and to evaluate the impact of additional controls and fixed effects. In all models, origin temperature has a positive and statistically significant effect on migration. Origin precipitation also shows a positive association in most models, except for Model 7, where the effect is negative. Origin GDP per capita is consistently positive and significant, suggesting that higher-income regions tend to have higher out-migration. Destination temperature shows a positive effect across relevant models. Destination precipitation has inconsistent effects, and its significance varies. The effect of destination GDP per capita is also mixed; it is significant in some models but not in others. From Model 5 onward, log distance is included and shows a negative effect on migration, consistent with distance-related migration costs. In Model 7, the number of refugees at the destination is positively associated with migration, which may reflect migrant network effects. Model 8 adds a law dummy variable, which also has a positive and significant effect, indicating that legal and institutional context can influence migration flows. The use of fixed effects across Models 2 to 4 and 6 to 8 helps control for unobserved heterogeneity related to time, origin, and destination regions. As more controls and fixed effects are added, model fit improves, with R-squared values increasing from 0.046 in Model 1 to 0.629 in Models 6 and 8. The Wald chi-square statistics indicate that the overall models are statistically strong.

Table 3 presents results from eight models using PPML and analyzing internal migration flows across Türkiye. The models are built progressively by including additional variables and fixed effects to test robustness. Across all models, origin temperature has a positive and statistically significant relationship with migration. Origin precipitation also shows a positive effect, though with some variation across specifications. Origin GDP per capita is positively associated with migration in most models, but shows a negative effect in Model 7. For destination characteristics, temperature is positively and significantly associated with migration, while precipitation generally shows a negative effect. Destination GDP per capita has mixed results, with both positive and negative coefficients depending on the model. From Model 5 onward, distance

is included and consistently shows a negative effect on migration flows. Model 7 includes the number of refugees in the destination region, which is positively associated with migration. Model 8 adds a law dummy variable, also showing a positive and significant effect. The inclusion of time-fixed, origin-fixed, and destination-fixed effects improves model fit, with pseudo R-squared values increasing from 0.005 in Model 1 to 0.0785 in Models 6 and 8.

Table 3: Whole Country Sample of Türkiye PPML Results

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Log origin temperature	0.237*** (0.006)	0.059*** (0.020)	0.058*** (0.020)	0.062*** (0.016)	0.251*** (0.005)	0.065*** (0.013)	0.149*** (0.007)	0.065*** (0.013)
Log origin precipitation	0.052*** (0.003)	0.016** (0.008)	0.018** (0.008)	0.017*** (0.006)	0.072*** (0.003)	0.018*** (0.005)	0.080*** (0.003)	0.018*** (0.005)
Log origin GDP per capita			0.092*** (0.019)	0.092*** (0.014)	0.046*** (0.005)	0.093*** (0.012)	-0.151*** (0.007)	0.093*** (0.012)
Log destination temperature				0.225*** (0.009)	0.264*** (0.005)	0.176*** (0.008)	0.242*** (0.007)	0.176*** (0.008)
Log destination precipitation					-0.032*** (0.004)	-0.026*** (0.003)	-0.015*** (0.003)	-0.029*** (0.003)
Log destination GDP per capita					-0.040*** (0.007)	0.155*** (0.005)	0.102*** (0.007)	0.157*** (0.007)
Log distance						-0.183*** (0.002)	-0.198*** (0.002)	-0.179*** (0.003)
Log number of refugee							0.073*** (0.001)	-0.198*** (0.002)
Law-dummy								0.111*** (0.005)
Constant	0.559*** (0.027)	1.143*** (0.079)	0.371** (0.182)	0.571*** (0.149)	-0.729*** (0.061)	0.526*** (0.133)	0.744*** (0.080)	0.526*** (0.133)
Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Origin FE	No	Yes	Yes	Yes	No	Yes	No	Yes
Destination FE	No	No	No	Yes	No	Yes	No	Yes
Observations	36,000	36,000	36,000	36,000	36,000	36,000	16,800	36,000
Pseudo R-squared	0.005	0.028	0.028	0.064	0.028	0.0785	0.033	0.0785

Note: All variables, except for the law dummy, are in logarithmic form. We used the Poisson Pseudo-Maximum Likelihood method and included control variables in the model. We also examined time-fixed, origin-fixed, and destination-fixed effects, with destination-fixed effects assessed after Model 4, which incorporates the control variables for destination cities. Robust standard errors are in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4 presents the Hausman-Taylor estimation results for the whole-country sample. This approach accounts for potential endogeneity in selected variables. In Model 1, origin GDP is treated as endogenous, while in Models 2 to 6, both origin and destination GDP per capita are treated as endogenous. Across all models, origin temperature has a positive and statistically significant association with migration. Origin precipitation also shows a positive effect in most models, except Model 4, where the coefficient is negative. Origin GDP per capita is positively associated with migration in all models, including when treated as endogenous. Destination GDP per capita shows mixed results: it is negative in Models 2 and 3, statistically insignificant in Model 4, and positive in Models 5 and 6. Destination temperature is positively associated with migration in all relevant models, while the effect of destination precipitation is generally small and statistically insignificant, except for Model 3, where the coefficient is negative. Distance, a time-invariant variable, has a consistent and significant negative effect across all models. The number of refugees at the destination is positively associated with migration in Model 4. The law dummy variable is included in Models 5 and 6 and shows a positive and significant association. Fixed effects are applied through the Hausman-Taylor method, allowing for the inclusion of time-invariant regressors. The models are statistically validated with Wald chi-square statistics, with values ranging from 1,290 in Model 4 to 9,490 in Model 6.

Table 4: Whole Country Sample of Türkiye Hausman-Taylor Results

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Log origin temperature	1.472*** (0.026)	0.988*** (0.030)	0.977*** (0.031)	0.217*** (0.055)	0.379*** (0.031)	0.391*** (0.031)
Log origin precipitation	0.091*** (0.009)	0.065*** (0.009)	0.064*** (0.009)	-0.096*** (0.009)	0.053*** (0.009)	0.055*** (0.009)
Log destination temperature		0.971*** (0.033)	0.973*** (0.032)	0.395*** (0.056)	0.555*** (0.032)	0.527*** (0.032)
Log destination precipitation		0.002 (0.010)	0.002 (0.009)	-0.094*** (0.011)	-0.002 (0.009)	0.000 (0.009)
Log origin GDP per capita	0.282*** (0.015)	0.320*** (0.022)	0.378*** (0.023)	0.174*** (0.035)	0.339*** (0.022)	0.284*** (0.022)
Log destination GDP per capita		-0.002*** (0.024)	-0.080*** (0.023)	-0.040 (0.035)	0.068*** (0.023)	0.128*** (0.023)
Log distance	-0.714*** (0.040)	-0.730*** (0.038)	-0.713*** (0.039)	-0.694*** (0.039)	-0.726*** (0.040)	-0.730*** (0.039)
Log number of refugee				0.106*** (0.005)		
Law-dummy					0.279*** (0.004)	0.223*** (0.005)
Log origin electricity consumption						0.000*** (0.000)
Constant	2.283*** (0.314)	0.941*** (0.312)	1.104*** (0.313)	6.963*** (0.441)	2.787*** (0.312)	2.647*** (0.310)
Observations	36,000	36,000	36,000	16,800	36,000	36,000
Number of id	2,400	2,400	2,400	2,400	2,400	2,400
Wald chi2	3640.55	4644.49	4562.17	1290	8998.69	9490.30

Note: All variables are analyzed in logarithmic form except the law dummy. GDP serves as the endogenous variable, while temperature, precipitation, the number of refugees, and the law dummy are exogenous. Nordhaus (2019) assumes that temperature is endogeneous variable however, Roberts et al. (2013) assumes the temperature exogeneous variable. In the first model, we use just the origin GDP as the endogenous variable. From Model 2 onward, both origin and destination GDP are treated as endogenous. Distance is considered a time-invariant variable. Robust standard errors are presented in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

7.2 The Drought Cities Sample of Türkiye

In this subsection, we will provide the results for the drought cities sample, which includes 17 origin cities, 15 years, and 80 destination cities, resulting in a total of 20,400 observations.

Table 5 presents pooled OLS regression results for drought-affected cities in Türkiye. In Model 1, origin temperature has a positive and significant effect on migration, but this effect is not consistent across other models. In contrast, origin precipitation shows a positive and significant association in most models, except for Model 7, where the coefficient is negative. Origin GDP per capita is positively associated with migration in all relevant models, supporting the role of economic factors in driving migration. For destination characteristics, temperature has a generally positive and significant effect, while precipitation shows mixed and mostly insignificant results. The effect of destination GDP per capita varies across models, with both negative and positive coefficients observed. Distance has a negative and statistically significant association with migration flows in Models 5 to 8, consistent with expectations. Model 7 includes the number of refugees in the destination city, which has a positive and significant effect. Model 8 introduces a law dummy variable, which also shows a positive and significant relationship with migration. Time-fixed, origin-fixed, and destination-fixed effects are added across models to improve specification. R-squared values increase from 0.107 in Model 1 to 0.605 in Models 6 and 8, indicating better model fit as more controls are introduced. Wald chi-square statistics support the overall model strength.

Table 6 presents PPML estimation results for the drought-affected cities sample in Türkiye. Across all models, origin temperature has a positive and statistically significant association with migration. Origin precipitation also shows a positive and significant effect in most models, including Models 1 and 5, though the magnitude varies. Origin GDP per capita is positively associated with migration in Models 3 and 6, but

shows a negative effect in Model 7. For destination variables, temperature has a consistently positive and significant association with migration. Destination precipitation displays negative and statistically significant coefficients across several models, indicating a potential deterrent effect. Destination GDP per capita shows mixed results, with both positive and negative effects across different specifications. Distance is included from Model 5 onward and consistently shows a negative and significant association with migration flows. In Model 7, the number of refugees at the destination is positively associated with migration. Model 8 includes the law dummy variable, which also shows a positive and significant effect. Time-fixed, origin-fixed, and destination-fixed effects are introduced progressively to improve the model. The pseudo R-squared values increase from 0.014 in Model 1 to 0.081 in Models 6 and 8, suggesting improved model fit.

Table 5: Drought Cities Sample of Türkiye Pooled OLS Results

VARIABLES	(1) model 1	(2) model 2	(3) model 3	(4) model 4	(5) model 5	(6) model 6	(7) model 7	(8) model 8
Log origin temperature	2.637*** (0.068)	0.148 (0.170)	-0.052 (0.159)	-0.042 (0.155)	1.637*** (0.070)	-0.049 (0.156)	0.466*** (0.108)	-0.049 (0.156)
Log origin precipitation	0.124*** (0.011)	0.064*** (0.010)	0.055*** (0.017)	0.055*** (0.018)	0.102*** (0.012)	0.054*** (0.018)	-0.212*** (0.013)	0.054*** (0.018)
Log origin GDP per capita			0.234*** (0.055)	0.234*** (0.053)	0.380*** (0.028)	0.237*** (0.053)	-0.016 (0.047)	0.237*** (0.053)
Log destination temperature				1.118*** (0.087)	1.065*** (0.046)	1.086*** (0.083)	0.709*** (0.071)	1.086*** (0.083)
Log destination precipitation				-0.020 (0.012)	0.003 (0.013)	-0.012 (0.013)	-0.045*** (0.015)	-0.012 (0.013)
Log destination GDP per capita				-0.033 (0.057)	-0.116*** (0.029)	0.266*** (0.061)	0.082** (0.047)	0.266*** (0.061)
Log distance					-0.712*** (0.046)	-0.815*** (0.043)	-0.769*** (0.049)	-0.815*** (0.043)
Log number of refugee							0.069*** (0.005)	
Law-dummy								0.488*** (0.023)
Constant	-3.467*** (0.230)	3.284*** (0.521)	1.957*** (0.686)	-0.076 (0.859)	-0.940** (0.399)	2.493*** (0.864)	7.245*** (0.645)	2.493*** (0.864)
Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Origin FE	No	Yes	Yes	Yes	No	Yes	No	Yes
Destination FE	No	No	No	Yes	No	Yes	No	Yes
Observations	20,400	20,400	20,400	20,400	20,400	20,400	9520	20,400
R-squared	0.107	0.318	0.318	0.489	0.302	0.605	0.262	0.605
Wald chi2	1511.20	4060	4207.67	5082.55	3618.91	6443.22	1117.71	6443.22

All variables, both dependent and independent, are analyzed in logarithmic form, except for the law dummy variable. Control variables were added to the model, and we accounted for time-fixed, origin-fixed, and destination-fixed effects, with destination-fixed effects assessed after Model 4, which includes destination-related control variables. Robust standard errors are in parentheses. Significance levels are indicated as: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7 presents the Hausman-Taylor estimation results for drought-affected cities in Türkiye. In Model 1, only origin GDP per capita is treated as endogenous, while from Model 2 onward, both origin and destination GDP per capita are considered endogenous variables. Across all models, origin temperature has a positive and statistically significant effect on migration, though the magnitude varies. Origin precipitation is also positively associated with migration in most models, except Model 4, where it has a negative coefficient. Origin GDP per capita is positively associated with migration across all models where included. Destination GDP per capita shows mixed results, including negative coefficients in Models 2 to 4 and a positive effect in Model 6. Destination temperature is positively associated with migration in all relevant models. Destination precipitation is mostly small and statistically insignificant, except for Model 3, which shows a negative effect, and Models 4 and 5, where coefficients are weakly positive. Distance is treated as a time-invariant variable and consistently has a negative and significant effect across all models. The number of refugees in the destination region has a positive and significant effect in Model 4. Models 5 and 6 include the law dummy, which is also positively and significantly associated with migration. Fixed effects are implemented through the Hausman-Taylor method, and Wald chi-square statistics across models confirm the robustness of the

results.

Table 6: Drought Cities Sample of Türkiye PPML Result

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Log origin temperature	0.237*** (0.006)	0.059*** (0.020)	0.058*** (0.020)	0.062*** (0.016)	0.251*** (0.005)	0.065*** (0.013)	0.149*** (0.007)	0.065*** (0.013)
Log origin precipitation	0.052*** (0.003)	0.016** (0.008)	0.018** (0.008)	0.017*** (0.006)	0.072*** (0.003)	0.018*** (0.005)	0.080*** (0.003)	0.018*** (0.005)
Log origin GDP per capita			0.092*** (0.019)	0.092*** (0.014)	0.046*** (0.005)	0.093*** (0.012)	-0.151*** (0.007)	0.093*** (0.012)
Log destination temperature				0.225*** (0.009)	0.264*** (0.005)	0.176*** (0.008)	0.242*** (0.007)	0.176*** (0.008)
Log destination precipitation					-0.032*** (0.004)	-0.026*** (0.003)	-0.015*** (0.003)	-0.023*** (0.003)
Log destination GDP per capita					-0.040*** (0.007)	0.155*** (0.005)	0.102*** (0.007)	0.157*** (0.007)
Log distance						-0.183*** (0.002)	-0.198*** (0.002)	-0.179*** (0.003)
Log number of refugee							0.073*** (0.001)	-0.198*** (0.002)
Law-dummy								0.111*** (0.005)
Constant	0.559*** (0.027)	1.143*** (0.079)	0.371** (0.182)	0.571*** (0.149)	-0.729*** (0.061)	0.526*** (0.133)	0.744*** (0.080)	0.526*** (0.133)
Observations	36,000	36,000	36,000	36,000	36,000	36,000	36,000	16,800
Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Origin FE	No	Yes	Yes	Yes	No	Yes	No	Yes
Destination FE	No	No	No	Yes	No	Yes	No	Yes
Observations	20,400	20,400	20,400	20,400	20,400	20,400	20,400	9,520
Pseudo R-squared	0.014	0.036	0.036	0.070	0.043	0.081	0.042	0.081

Note: All variables, both dependent and independent, are in logarithmic form except for the law dummy, since it is a dummy variable. We applied the Poisson Pseudo-Maximum Likelihood method. Control variables were added to the model, and we checked for time-fixed effects, origin-fixed effects, and destination-fixed effects. Destination-fixed effects were checked after Model 4, which includes the control variables related to destination cities. Robust standard errors are in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Our results reveal that climate change significantly affects migration patterns in Türkiye. We used temperature and precipitation as proxies for climate change. Higher temperatures in origin cities positively influence migration, particularly during hot summers when people decide to move to more temperate areas. This is reasonable considering Türkiye's climate, where some drought-affected cities become extremely hot in the summer, prompting residents to seek better climates elsewhere. Regarding destination decisions, people prefer warmer places, indicating that while they want to escape extreme heat, they do not want to move to very cold areas either. This aligns with the saying that people "vote with their feet" (Rappaport, 2009). Some researchers have also found similar results, indicating that temperature increases enhance migration (Backhaus et al., 2015; Beine and Parsons, 2015, 2017; Ruiz et al., 2017).

We find that precipitation in origin cities is positively associated with migration in most model specifications. While this may initially appear counterintuitive, it is consistent with the idea that climate-related factors can affect mobility through income channels. The relationship may reflect the role of precipitation in supporting agricultural productivity in some regions, which could influence migration decisions indirectly through household income or employment stability. However, our data do not include sector-specific economic activity or agricultural output, so we cannot confirm this mechanism directly. In our theoretical framework (Equation (27)), migration costs rise with distance, requiring sufficient economic resources to overcome them. This is supported by the positive and significant effect of origin GDP per capita on migration observed in our empirical results. While prior studies have noted similar links between income and migration propensity (Marotzke et al., 2020; Gillis et al., 2023), further research is needed to test whether precipitation affects migration specifically through income effects among agricultural populations.

Table 7: Drought Cities Sample of Türkiye Hausman-Taylor Results

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Log origin temperature	2.661*** (0.053)	1.588*** (0.072)	1.629*** (0.071)	0.251** (0.105)	0.418*** (0.073)	0.283*** (0.073)
Log origin precipitation	0.139*** (0.011)	0.095*** (0.012)	0.098*** (0.012)	-0.226*** (0.013)	0.041*** (0.012)	0.043*** (0.011)
Log destination temperature		1.063*** (0.047)	1.054*** (0.047)	0.600*** (0.076)	0.828*** (0.046)	0.812*** (0.045)
Log destination precipitation		0.007 (0.013)	0.006 (0.013)	-0.032** (0.014)	0.027** (0.012)	0.042*** (0.012)
Log origin GDP per capita	0.231*** (0.020)	0.410*** (0.029)	0.359*** (0.029)	0.107** (0.043)	0.316*** (0.028)	0.277*** (0.028)
Log destination GDP per capita		-0.187*** (0.031)	-0.113*** (0.030)	-0.149*** (0.042)	-0.014 (0.030)	0.093*** (0.030)
Log distance	-0.753*** (0.052)	-0.694*** (0.051)	-0.714*** (0.051)	-0.715*** (0.053)	-0.760*** (0.053)	-0.769*** (0.052)
Log number of refugee				0.062*** (0.005)		
Law-dummy					0.270*** (0.006)	0.185*** (0.007)
Log origin electricity consumption						0.000*** (0.000)
Constant	-0.733* (0.426)	-0.531 (0.423)	-0.725* (0.423)	8.815*** (0.617)	3.074*** (0.433)	2.602*** (0.428)
Observations	20,400	20,400	20,400	9,520	20,400	20,400
Number of id	1,360	1,360	1,360	1,360	1,360	1,360
Wald chi2	2895.04	3522.09	3501.22	951.20	5835.50	6365.35

Note: All variables are in logarithmic form except for the law dummy. We use GDP as an endogenous variable. Temperature, precipitation, the number of refugees, and the law dummy are considered exogenous variables. Nordhaus (2019) assumes temperature is an endogenous variable, while Roberts et al. (2013) treats it as an exogenous variable. In the first model, we use just the origin GDP as the endogenous variable. In the first model, we use the origin GDP as the endogenous variable. Starting from Model 2, we use both origin GDP and destination GDP as endogenous variables. Distance is treated as a time-invariant variable. Robust standard errors are in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Our results also show that greater distances reduce migration costs, as distance serves as a proxy for travel costs that affect migration decisions. Individuals often prefer destinations that allow easy visits to their hometowns, leading to increased travel and associated costs with longer distances. Therefore, distance plays a significant role in migration decisions, consistent with the gravity model of migration.

Our results show that an increase in the number of refugees leads to higher migration, with the effect significantly influenced by the number of refugees and the presence of a law dummy variable. This underscores the critical role that both refugee numbers and legal frameworks play in shaping migration patterns.

We also include electricity consumption in origin cities as a control variable. The coefficient is statistically significant in some specifications, but its magnitude is close to zero. This result is likely due to the relative scales of electricity consumption and migration flows rather than evidence of a substantive effect. While electricity use may be correlated with climate-related living costs, our data do not allow us to identify the mechanisms through which energy use might influence migration. We therefore treat this variable primarily as a control to capture variation in urban economic activity and energy demand, rather than as a direct driver of migration.

We also include electricity consumption in origin cities as a control variable. The coefficient is statistically significant in some specifications but very close to zero. This result should not be interpreted as a substantive

effect on migration decisions; rather, it likely reflects the difference in scale between electricity consumption (measured in large units) and migration flows (measured as relatively small rates). Electricity consumption is therefore treated primarily as a control variable that captures variation in local economic activity and energy demand, rather than as a direct determinant of migration.

Overall, our results show that climatic and economic variables are consistently associated with internal migration patterns in Türkiye. Temperature and precipitation at the origin, income levels, distance, and institutional factors such as refugee presence and migration-related laws all exhibit statistically significant relationships with migration flows. These associations are robust across alternative model specifications and estimation methods, indicating stable empirical patterns.

8 Discussion

This study examined the relationship between climate, economic, and institutional factors and internal migration in Türkiye using pooled OLS, Poisson Pseudo-Maximum Likelihood, and Hausman-Taylor estimators, grounded in the Random Utility and Gravity Model frameworks. The results consistently show that higher average temperatures and greater precipitation in origin cities are positively associated with migration flows. At the destination, temperature is also positively associated with migration, while precipitation shows mixed effects depending on the specification. Higher GDP per capita in origin regions is associated with increased out-migration, whereas greater distance between origin and destination is negatively associated with migration, consistent with gravity model predictions. In addition, the presence of refugees and migration-related laws in destination cities is positively correlated with migration flows, highlighting the importance of institutional and demographic context in shaping internal migration patterns.

Our findings challenge the initial expectations in equation (18), which predicted that rising temperatures would increase migration while increased precipitation would reduce it. Contrary to these expectations, our results show that both higher temperatures and increased precipitation in origin cities significantly drive migration flows in Türkiye. Specifically, while equation (18) anticipated that extreme temperatures would worsen living conditions and thus increase migration, our analysis confirms that extreme heat, in southern Türkiye, where the yearly average temperature is around 18 degrees Celsius, climbing to over 30 degrees Celsius in summer, strongly compels individuals to move to cooler areas, validating the "voting with their feet" concept (Rappaport, 2009; Backhaus et al., 2015; Cai et al., 2016; Thiede et al., 2016)²⁴. Conversely, contrary to the expectation that increased precipitation would reduce migration by enhancing local resources, we found that higher rainfall actually correlates positively with migration rates (Backhaus et al., 2015; Hirvonen, 2016). This indicates that increased precipitation improves agricultural productivity and economic conditions, thereby facilitating migration through enhanced financial means (Beine and Parsons, 2017; Mahajan and Yang, 2020).

The Gravity Model is particularly well-suited for this analysis, as it captures the proportional relationship between migration flows, the economic size of locations, and the distance between them. By incorporating origin and destination variables such as GDP, temperature, and precipitation, the model allows us to examine how both economic and climatic conditions shape migration patterns. PPML provides robustness to zero flows and heteroskedasticity, yielding consistent estimates even when many city pairs report no migration (Silva and Tenreyro, 2006). The Hausman-Taylor estimator addresses endogeneity and unobserved heterogeneity by decomposing the error term into individual-specific and idiosyncratic components, producing reliable estimates for both time-varying and time-invariant variables (Hausman and Taylor, 1981; Wooldridge, 2010).

The influx of approximately five million refugees into Türkiye has significantly altered internal migration dynamics. This large-scale refugee presence has strained local resources and heightened social tensions, prompting some residents to relocate. We incorporate refugee burden into our analysis to capture this effect. The arrival of refugees, particularly from Syria, Afghanistan, and several African countries, has compounded internal migration pressures (Sagiroglu; Erdoğan and Cantürk, 2022).

²⁴In future work, the model could be reformulated without imposing sign restrictions on temperature and precipitation, allowing for potentially non-monotonic effects. It would also be informative to examine seasonal or monthly temperature and precipitation data, and to test whether migration patterns differ between southern origin cities and more temperate northern destinations.

Climate change further exacerbates environmental stressors such as droughts, which contribute to resource scarcity and competition. These pressures can heighten the risk of conflict, as illustrated in Syria, where prolonged droughts weakened agricultural systems and contributed to civil unrest (Kelley et al., 2015). Such conflicts force people to migrate in search of safety, creating large-scale displacement. The resulting refugee influx has strained host communities and generated secondary migration, as both refugees and locals relocate in search of opportunities (Rapoport et al., 2020). Climatic shocks that reduce agricultural yields can drive food insecurity, increasing the likelihood of violence (Raleigh, 2011; Bozkurt and Sen, 2013; Moore and Wesselbaum, 2023). For instance, Hendrix and Salehyan (2012) demonstrates that both extreme wet and dry conditions in Africa are correlated with civil strife, further linking climate variability to conflict.

The Syrian civil war, which began in 2011, has been partially linked to the severe drought of 2007–2010, the most intense in the country’s recorded history. Kelley et al. (2015) show that this drought intensified pre-existing vulnerabilities, triggered widespread agricultural failures, and displaced up to 1.5 million rural residents to urban centers, fueling social tensions and instability. According to UNHCR,²⁵ since 2011 more than 14 million Syrians have been forced to flee their homes, with roughly four million settling in Türkiye.

Migration reshapes both migrant and host communities. Large inflows strain housing, healthcare, and labor markets, and can generate social tensions and political backlash. Migrants, in turn, face barriers to integration, including language differences, cultural adjustment, and limited social support (Koubi et al., 2016; Rapoport et al., 2020). Adida et al. (2017) highlight the wider social and political challenges associated with refugee crises, underscoring the need for policy responses that address both host-community concerns and migrant vulnerabilities. Similarly, Gillis et al. (2023) emphasize how climate-induced migration generates mixed social responses, reinforcing the importance of integrating climate and refugee dynamics into migration policy.

In summary, our findings emphasize the complex interaction between climate change and migration. Addressing these challenges requires coordinated policies that account for both environmental and refugee-related pressures to manage migration effectively and mitigate its compounded effects.

Conclusion

This study examined the relationship between climatic and economic factors and internal migration flows in Türkiye using pooled OLS, Poisson Pseudo-Maximum Likelihood, and Hausman-Taylor estimators, grounded in the Gravity and Random Utility Model frameworks. Across all specifications, we find that higher average temperatures and greater precipitation in origin cities are positively associated with migration. Destination temperature also shows a positive association, while precipitation exhibits mixed effects. Higher GDP per capita in origin regions is correlated with increased out-migration, and distance consistently reduces migration flows, in line with gravity model predictions. These results demonstrate that both climatic and economic conditions are systematically related to migration decisions.

We also account for the presence of refugees in destination regions, treating this as a secondary factor that shapes the broader migration environment. While refugee inflows are not the focus of our analysis, they provide important context, as they can influence local conditions and interact with climate-driven mobility pressures.

Overall, our findings highlight the importance of integrating climatic variables into the study of internal migration. Rising temperatures and shifting precipitation patterns are likely to remain significant drivers of population movements in Türkiye. Addressing these challenges requires policies that account for both environmental pressures and the broader socio-economic context in which migration occurs. Future work should incorporate higher-frequency climatic data, such as seasonal or monthly averages, and explore heterogeneity across regions to better identify the mechanisms through which climate influences migration.

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²⁵Data source: <https://www.unrefugees.org/>

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