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# Rainfall shocks, per capita income and rural out-migration

**Nathan Delacrétaz, Bruno Lanz, Amir H. Delju and Étienne Piguet**

# Rainfall shocks, per capita income and rural out-migration\*

Nathan Delacrétaz<sup>†</sup>   Bruno Lanz<sup>‡</sup>   Amir H. Delju<sup>§</sup>   Etienne Piguet<sup>¶</sup>

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## Abstract

Rural regions are more exposed to rainfall shocks, notably through agriculture, and understanding how local population adapt to changes in the climate is an important policy challenge. In this paper we exploit longitudinal data for Turkish provinces from 2008 to 2018 together with precipitation records over more than 30 years to study how shocks to 12-month standard precipitation index (SPI) affect out-migration across rural, transitional and urban regions, and we document how these impacts are channeled through local income, agricultural GDP, and conflicts. Based on fixed effect regressions controlling for unobserved heterogeneity across provinces and over time, we find evidence that negative SPI shocks are associated with higher out-migration in rural provinces. We also show that the relationship is fully mediated by per capita GDP, whereas agricultural GDP and conflicts do not play a role.

**Keywords:** out-migration; climate change; rainfall; urbanization; per capita income; agriculture; conflicts.

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# 1 Introduction

Ongoing changes in the climate system are responsible for an increased frequency of extreme weather events (IPCC, 2018). Because human societies fundamentally rely on the climate to sustain themselves, formulating adaptation policies requires an understanding how local shocks affect population dynamics. In particular, results from interdisciplinary research at the farm level suggests that extreme weather events are a key detrimental determinant of agricultural yields (e.g., Schlenker and Roberts, 2009; Burke and Lobell, 2010).<sup>1</sup> In turn, societies with predominantly rural population who rely on agriculture for subsistence and income are more exposed to climate shocks, and understanding adaptation mechanism in these regions is highly policy relevant.

One important adaptation margin often considered by policy makers is migration (Boas et al., 2019; Borderon et al., 2019; Hoffmann et al., 2020), and in this paper we provide novel evidence on how rainfall shocks affect out-migration decisions. In order to account for heterogeneity in local impacts, including through economic and social conditions, we consider the rural to urban dimension as a moderating factor (see Cattaneo et al., 2019). More specifically, we document the extent to which a given shock to precipitation can act as a “push factor” in migration decisions for households living in areas classified as rural, transitional or urban.

We further consider three specific channels that can mediate the relationship between rainfall shocks and out-migration. The first is agricultural output (Feng et al., 2010; Cai et al., 2016), which builds on empirical evidence at the farm level. We note, however, that poverty and subsistence constraint can also imply a reduction in migration (Cattaneo and Peri, 2016). As a second channel, we consider per capita GDP (Beine and Parsons, 2015; Mastrorillo et al., 2016), which captures broader regional impacts associated with local climate-induced shocks. Lastly, we study the role of conflicts, as put forward by a growing literature (e.g. Burke et al., 2009; Kelley et al., 2015; Abel et al., 2019), and use data from the Uppsala Conflict Data Program data to quantify whether conflict-related fatalities mediates the effect of rainfall shocks on out-migration.

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<sup>1</sup> The empirical relationship between extreme weather events and yields is also documented in Jayachandran (2006), Iizumi and Ramankutty (2015), Fezzi and Bateman (2015), Ochieng et al. (2016), among others.

Our work is based on longitudinal data for 71 Turkish provinces from 2008 to 2018. This is important for at least two reasons. First, while a large strand of research on climate-induced migration is conducted in low-income countries, research on middle-income countries remains scarce (Cattaneo et al., 2019; Hoffmann et al., 2020). With almost fifty provinces being predominantly rural, but surrounded by either transitional or urban regions, our work contributes to an understanding of how rural communities adapt to climate change in a context of urbanization and structural change. Second, the Turkish Statistical Institute (TSI) provides high-quality provincial data including out-migration, GDP per capita, and agricultural GDP per capita, as well as a host of other socio-demographic characteristics for each province (see also Delju et al., 2019). Similarly, the Turkish State Meteorological Service (TSMS) offers long-term precipitation records, with station-level measurement available for more than thirty years. We use this data to compute a 12-month Standard Precipitation Index (SPI), which allows us to characterize yearly deviations from the long-run distribution of precipitation at the provincial level.<sup>2</sup>

Based on these data, we estimate the impact of SPI shocks on out-migration across provinces in Turkey. Having ten years of data for each province allows us to introduce province-level fixed effects to control for any time-invariant characteristics of the province that could affect out-migration. This would, for example, capture the fact that population in rural regions tend to be relatively young, and that these regions also tend to experience higher out-migration on average (see below). Our analysis also controls for year fixed effects to factor out the passage of time (see Auffhammer and Vincent, 2012), which would capture any temporal trend in rural to urban migration. In addition, we consider a number of control variables capturing province-level characteristics that have been shown to be drivers of out-migration (e.g., education). Taken together, our empirical strategy allows us to identify the extent to which random deviations from the regime of precipitation observed over the previous thirty years acts as a push-factor in decisions to migrate out of respective provinces, controlling for other push and pull factors (e.g., living in an arid area or being located near a urban agglomeration).

Building on this baseline specification, which is a well-established workhorse in the empiri-

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<sup>2</sup> We choose to use a 12-month SPI so as to capture yearly rainfall shocks over the growing season. However, Turkey includes several climatic regions with different agricultural systems, and below we discuss the robustness of our results to alternative measures of rainfall shocks.

cal literature, our contribution is twofold. First, we employ the multi-criteria analysis of Oğdül (2010) to classify each province as predominantly rural, transitional or urban. We then use this classification as a moderator to estimate the impact of SPI shocks across provinces of different types.<sup>3</sup> Second, we use a mediated-moderator analysis to quantify how the impact of SPI on out-migration is mediated by GDP per capita, the agricultural GDP per capita and conflict fatalities, and how the mediated effects differ across provinces classified as rural, transitional or urban.<sup>4</sup> More specifically, in a first step we identify the impact of SPI shocks (the treatment variable) on each potential mediating variable, testing for differences across our urban-rural categorization (the moderating variable). In a second step, we estimate the impact of SPI shocks on out-migration controlling for each potential mediating variable. This allows us to consistently compare the role of alternative channels in the relationship between rainfall shocks and out-migration across urban and rural provinces.

Empirical evidence derived from our data confirms that SPI shocks affect out-migration, although only in rural areas, with years subject to below-average SPI implying an increased number of emigrants. Quantitatively, we find that a decrease of the SPI by one standard deviation increases out-migration in rural provinces by 0.49 thousand emigrants on average, or around 3 percent of yearly out-migration in rural provinces. We then show that this effect in rural provinces is fully mediated by GDP per capita, meaning that negative SPI shocks reduce economy-wide income in rural areas, which in turn acts as a push factor triggering out-migration. By contrast, and perhaps surprisingly, the data do not provide evidence that per capita agricultural GDP and the number of conflict fatalities mediate the effect of SPI shocks on out-migration.

These results contribute to a growing literature on the linkages between climate change and migration. While empirical evidence on this issue remains controversial (see Boas et al., 2019, for a discussion), a number of empirical studies for low-income countries provide evidence of

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<sup>3</sup> As a robustness check, we also consider alternative measures to identify rural areas (e.g., the share of population living in cities with more than 350,000 inhabitants). We come back to this below.

<sup>4</sup> The mediated-moderator approach combines a mediation analysis, which identifies a causal sequence between two variables and an outcome, and a moderator analysis, which identifies the effect of a variable on the relationship between another variable and an outcome. See for example Muller et al. (2005), Morgan-Lopez and MacKinnon (2006), MacKinnon et al. (2007).

rural-urban migration in relation to temperature shocks. This includes Marchiori et al. (2012) for sub-Saharan Africa, Viswanathan and Kumar (2015) for India, and De Longueville et al. (2019) for Burkina Faso. Using cross-country data, Maurel and Tuccio (2016) document an impact of increasing temperature trends on urbanization, whereas Cattaneo and Peri (2016) show that poverty may prevent population movements in low-income countries, but increase it in middle-income countries.<sup>5</sup> This is supported by evidence reported in Nawrotzki et al. (2016) for Mexico, and Thiede et al. (2016) and Baez et al. (2017b) for South America, although further evidence on middle-income countries is needed (see Cattaneo et al., 2019, for a discussion).

We also contribute to a literature that attempts to identify the mechanism linking climate shocks and migration. For example, Cai et al. (2016) show that temperature has a significant impact on out-migration in countries with an important agricultural sector. Using SPI to measure climate variability, Dallmann and Millock (2017) find that drought induces rural-rural interstate migration in India through impacts on both agricultural and total income. Similarly, Bertoli et al. (2020) report that drought increases the probability of intending to migrate, especially for low-skilled workers of rural areas, in Senegal, Niger, and Ivory Coast. Another important mechanism in relation to climate shocks is conflicts (Burke et al., 2015). Kelley et al. (2015) argue that a severe drought contributed to trigger social unrest in 2011 Syria, and being ultimately associated with mass migration, although this remains a contentious interpretation (see Selby et al., 2017; Selby, 2019). Missirian and Schlenker (2017) estimate that temperature deviations that affect agricultural yields are associated with increased asylum applications in the European Union (see also Abel et al., 2019; Cottier and Salehyan, 2021). Relative to these studies, we document the role of alternative channels in a consistent framework, showing that the mediating role differs across regions that are predominantly rural or urban.

Finally, existing empirical evidence reveals that socio-demographic factors are essential in understanding migration decisions. Among these, gender plays a role as a driver of migration, although the specific context determines whether male or female are more prone to emigrate (see Nawrotzki et al., 2016; Ezra and Kiros, 2001; Gray and Mueller, 2012; Debnath and Nayak, 2020). In addition, Baez et al. (2017a) shows that education and the population age structure

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<sup>5</sup> Benonnier et al. (2019) provide evidence that access to irrigation moderates the temperature-migration relationship, as it shelters yields from weather shocks.

determine out-migration trends, as younger and more educated populations tend to have a higher probability to emigrate so as to seek economic opportunities (see also Findley, 1994; Kabir et al., 2018). As we discuss below, the set of control variables included in our analysis is selected in light of this evidence.

The remaining of this paper is structured as follows. Section 2 describes our empirical strategy, including our rural-urban classification and our mediated-moderator approach. Section 3 shows a summary of our data and reports estimation results. Finally, Section 4 briefly discusses the results and concludes.

## 2 Methods: Empirical strategy

This section discusses our empirical strategy. We first focus on our main specification to identify the impact of SPI shocks on out-migration across a rural-urban classification of Turkish provinces. Next, we discuss how we identify the role of alternative channels. Lastly, we describe how we check the robustness of our main results.

### 2.1 Estimation of the main effects

Our empirical strategy is guided by the climate change and migration meta-analysis of Beine and Jeusette (2021). Our objective is to quantify how random shocks in precipitations occurring in province  $i$  and year  $t$ , as measured by variability in the 12-month SPI (denoted  $SPI_{i,t}$ ), affects provincial out-migration over the same year  $t$  (denoted  $out-migration_{i,t}$  and measured in thousands of emigrants).<sup>6</sup> Formally, our main regression specification is given by:

$$out-migration_{i,t} = \alpha_i + \beta SPI_{i,t} + \gamma X_{i,t} + \delta_t + \epsilon_{i,t}, \quad (1)$$

where  $\alpha_i$  is a set of province fixed effects capturing any time-invariant factors that affect differences in out-migration across provinces and  $\delta_t$  is a set of year fixed effects absorbing macro

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<sup>6</sup> Bilateral migration data is in general preferred, see for example Beine and Parsons (2015), Dallmann and Millock (2017) and Abel et al. (2019). Such data is, however, not available at the provincial level in Turkey, so we rely on out-migration to identify the role of climate as a push-factors in migrations decisions. For other analysis of out-migration data, see for example Feng et al. (2010), Neumann et al. (2015), Nawrotzki et al. (2016), or Debnath and Nayak (2020).



shocks common across provinces. The vector of control variable  $X_{i,t}$  includes three main drivers in the propensity to emigrate. First, we include the share of population with primary education, the share of population with higher education and the share of young adults (aged 15 to 24) in the population (see Findley, 1994; Baez et al., 2017a; Kabir et al., 2018). Second, we control for the share of men per women (the sex ratio, see Gray and Mueller, 2012; Nawrotzki et al., 2016; Debnath and Nayak, 2020). Third, we include population density lagged by one year to mitigate endogeneity associated with this variable (Burke et al., 2009; Couttenier and Soubeyran, 2014). Finally,  $\epsilon_{i,t}$  is an error term.

The coefficient of interest is  $\beta$ . The associated variable  $SPI_{i,t}$  is derived from monthly precipitation measurements over the whole territory of Turkey, from 1970 to 2020. Specifically, we construct a 12-month SPI for a set of 71 provinces with at least 30 years of historical precipitation measurements, capturing yearly standard deviation divergence with respect to historical average computed over 30 years.<sup>7</sup> Notionally, the SPI index allows for comparison of precipitation shocks between provinces with different climates. Moreover, we emphasize that the choice of a 12-month period allows us to focus on medium-term drought shocks (Svoboda et al., 2012), and thereby broadly captures agricultural growing season.<sup>8</sup> In the robustness analysis, discussed below, we consider alternative approaches to measure rainfall shocks.

Next, we document how the impact of the SPI on out-migration differs across rural, transitional, and urban provinces. To do so, we exploit the detailed multi-criteria analysis of Oğdül (2010) who provides a classification of Turkish districts as rural, transitional or urban. The classification is based on six categories of socio-demographic characteristics: agricultural production, non-agricultural production, employment structure, demography, educational level, and trade opportunities.<sup>9</sup> A province is then defined as rural if 50% or more of its constituting

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<sup>7</sup> Specifically, a 12-month SPI is a comparison of total precipitation during 12 consecutive months in year  $t$  with an average for the same 12 consecutive months observed over thirty years of historical data. We aggregate station-level data by computing monthly averages for each province. We then generate our SPI variable using the Standard Precipitation Index Generator software of the National Drought Mitigation Center from the University of Nebraska. The analysis only considers provinces with complete precipitation data.

<sup>8</sup> To fully capture agricultural impacts, it would be necessary to define a set of province-specific SPI according to the growing season of each province (e.g., Unal et al., 2003; Deniz et al., 2011). However, due to the complexity and variety of climates across Turkish provinces, we choose to use a more global measure to capture annual trends.

<sup>9</sup> See Appendix A for a comprehensive list of factors included in the analysis carried out in Oğdül (2010).

Figure 1: Classification of Turkish provinces (source: Oğdül, 2010)



districts are classified as rural, it is defined as urban if 50% or more of its districts are urban, and it is a transitional province if it is neither rural nor urban. The resulting allocation is illustrated in Figure 1 and comprises 32 rural provinces, 34 transitional provinces and 5 urban provinces. In the robustness checks section below we discuss alternative approaches to distinguish between rural and urban provinces.

Based on this classification, we estimate separate  $\beta$  coefficients by defining three moderating variables:  $Rural_i$  is equal to one if province  $i$  is predominantly rural, zero otherwise;  $Urban_i$  is one if  $i$  is predominantly urban, zero otherwise; and  $Transitional_i$  equals one if  $i$  is neither predominantly urban nor rural, zero otherwise. Formally we estimate the following specification:

$$out-migration_{i,t} = \alpha_i + \beta_1 SPI_{i,t} \times Rural_i + \beta_2 SPI_{i,t} \times Transitional_i + \beta_3 SPI_{i,t} \times Urban_i + \gamma X_{i,t} + \delta_t + \epsilon_{i,t} . \quad (2)$$

By interacting the variable  $SPI_{i,t}$  with our classification of provinces, we quantify how SPI shocks affect out-migration in rural provinces, and whether estimated effects differ from those observed for transitional and urban provinces.

## 2.2 Estimation of potential channels: mediated-moderator analysis

We consider three potential mediating variables in the relationship between SPI and out-migration, namely GDP per capita, agricultural GDP per capita and conflict fatalities. The first two variables are available from TSI over the period of interest, whereas the number of conflict fatalities is taken from the Uppsala Conflict Data Program. Specifically, we exploit data about the location of conflict fatalities reported each year to determine the total number of fatalities per year and province over the period of observation.

In order to quantify the relevance of each potential channel, we employ the mediated-moderator specification of Morgan-Lopez and MacKinnon (2006). Starting from our main specification in equation 2, this requires two steps. In a first step, we estimate the impact of SPI shocks on each of our three mediating variables, denoted  $Y_{i,t}$ , and use the set of urban-rural indicator as moderating variables:

$$Y_{i,t} = \eta_i + \phi_1 SPI_{i,t} \times Rural_i + \phi_2 SPI_{i,t} \times Transitional_i + \phi_3 SPI_{i,t} \times Urban_i + \theta X_{i,t} + \chi_t + \varepsilon_{i,t}, \quad (3)$$

where the notation follows the same logic as above. This allows to test whether the moderated treatment variable has an impact on the mediator, a necessary condition for mediated-moderator analysis (MacKinnon et al., 2007).

The second step of our channel analysis quantifies the impact of SPI shocks on out-migration controlling for each respective mediating variables (GDP per capita, the agricultural GDP per capita or conflicts). This augments equation 2 as follows:

$$out-migration_{i,t} = \alpha_i + \beta_1 SPI_{i,t} \times Rural_i + \beta_2 SPI_{i,t} \times Transitional_i + \beta_3 SPI_{i,t} \times Urban_i + \psi Y_{i,t} + \gamma X_{i,t} + \delta_t + \epsilon_{i,t}. \quad (4)$$

Intuitively, while estimates in equation 3 quantify the relationship between the moderated treatment and each mediating variable, those in equation 4 quantify the magnitude of the indirect effect linking each mediating variable and the outcome.

### 2.3 Robustness checks

We conduct robustness checks in the following dimensions: (i) the definition of the SPI and drought events; (ii) our rural-urban classification of provinces; and (iii) the measures of migrations. In the following we briefly explain how we implement these.

Starting with SPI shocks, we first consider the possibility of more long-term impact, using 24-month and 36-month SPIs. This allows us to evaluate the impact of longer deviations to the historical precipitation average. Next, we re-estimate equation 1 with a 1-year lagged value for the SPI in order to test for year-on-year spillover effects. We then consider a specific definition of drought events, and construct of an indicator for short-term drought equal to one when the 12-month SPI is smaller or equal -1 in a given year, zero otherwise. In addition, we also consider a more long-term indicator for drought specified as the sum of successive years with a SPI smaller or equal to -1. Lastly, instead of our SPI index, we introduce monthly average precipitation per year and province in the estimation of equation 1.

Turning to our rural-urban classification, we employ two alternative measures captures key differences across provinces: (i) the share of provincial population living in cities with more than 300'000 inhabitants, and (ii) the share of provincial population working in agriculture. We therefore re-estimate equation 1 interacting the 12-months SPI with each variable to document whether the  $\beta$  estimates varies along with these dimensions. Related to that, we consider the possibility that access to irrigation may be different in rural, transitional and urban areas, which may in turn buffer local shocks (as in Benonnier et al., 2019). We therefore use TSI data for the share of irrigated agricultural area in each province (available for 2003) and interact it with our variable of interest. Finally, we consider how the conclusions from our main specification (equation 2) are affected by the use of alternative outcome variable, and re-estimate our main equation by scaling out-migration with population. Similarly, we estimate results for log-transformed out-migration, yielding proportional (percentage) results. Lastly, we exploit data on net migration rates, defined as the difference between in-migration and out-migration, scaled by population.

### **3 Data and results**

This section reports our empirical results. First, we summarize a number of key feature of our data. Second, we present the results from our main specification, documenting the impact of SPI shocks on out-migration across rural-urban classification. Third, we discuss the results of our channel analysis. Fourth, we present results of the robustness checks.

#### **3.1 Descriptive statistics**

Table 1 summarizes the data across our rural-urban classification. On average across all provinces out-migration is 31.78 thousands of emigrants each year, or around 4 percent of the provincial population. Out-migration tends to be larger and more volatile in provinces classified as urban, although as a percentage to total population it is larger in rural provinces (4.82%) relative to both transitional (3.85%) and urban (3.34%) provinces. By contrast, the mean of 12-month SPI is very similar across provinces, indicating that yearly mean precipitations are on average slightly higher over the observation period relative to the historical average.

Other variables follow an expected pattern, with GDP per capita being significantly higher in urban provinces, followed by transitional and rural provinces, whereas agricultural GDP per capita is similar among rural and transitional provinces but substantially higher than in urban provinces. We also note that the number of conflict fatalities is, on average, around two times larger in rural provinces, although the maximum is relatively close for rural and transitional provinces, and significantly lower in urban provinces. Overall, observed differences in socio-demographic characteristics support the use of fixed effects and control variables in order to quantify the impact of SPI shocks on out-migration.

#### **3.2 The impact of SPI shocks on out-migration across rural, transitional and urban provinces**

Table 2 reports our baseline empirical results. Column 1 is a simple bivariate regression of SPI on out-migration with no fixed effects and no additional control variable. In column 2 we add province and year fixed effects to respectively control for all time-invariant provincial characteristics and common macro shocks. In column 3 we add a vector of socio-demographic

Table 1: Descriptive statistics across Turkish provinces

	Mean	Std. Dev.	Min	Max
<i>Rural provinces (N=32)</i>				
Out-migration	19.07	10.41	4.09	62.21
12-month SPI	0.17	1.05	-2.98	2.82
GDP per capita	6.72	1.63	2.73	11.64
Agricultural GDP per capita	2.76	1.65	0.4	11.61
Conflict fatalities	0.07	0.31	0	3.77
Primary education	14.14	3.29	6.23	21.9
Higher education	19.5	3.6	11.06	28.78
Sex ratio	102.65	6.25	95.23	137.82
Young population	18.49	2.89	13.6	28.9
Population density	5.7	4.72	1	29.7
<i>Transitional provinces (N=34)</i>				
Out-migration	30.93	27.23	4.61	221.75
12-month SPI	0.19	1.06	-2.57	3.23
GDP per capita	8.99	2.67	3.31	17.59
Agricultural GDP per capita	2.84	1.36	0.4	7.61
Conflict fatalities	0.03	0.23	0	3.56
Primary education	13.24	3.16	7.24	22.8
Higher education	21.2	3.67	10.52	31.55
Sex ratio	100.8	3.29	96.73	132.79
Young population	16.45	1.92	12.8	25.6
Population density	9.42	6.22	2.2	28.7
<i>Urban provinces (N=5)</i>				
Out-migration	118.91	147.72	6.54	595.8
12-month SPI	0.2	1.12	-2.09	2.9
GDP per capita	14.77	3.08	8.96	20.73
Agricultural GDP per capita	0.92	0.68	0.04	2.27
Conflict fatalities	0.03	0.17	0	1.16
Primary education	13.21	3.18	8.08	18.82
Higher education	24.9	1.14	22.65	27.63
Sex ratio	101.83	2.34	99.29	107.27
Young population	15.35	0.78	13.5	17.1
Population density	79.07	98.45	12.2	290

Notes: Data sources are TSI, TSMS and Uppsala Conflict Data Program, from 2008 to 2018. *Out-migration* is in thousand of emigrants. *Conflict fatalities* is the number of fatalities reported for local conflicts (in hundred). *Primary education* and *Higher education* are the share of population above 15 years with primary and higher education respectively. *Sex ratio* is the ratio of male to female. *Young population* is the share of population between 15 to 24 years.

control variables (equation 1). In columns 4 and 5 we estimate separately SPI impacts for rural, transitional and urban provinces (equation 2), respectively without and with control variables. In all columns we report standard errors clustered at the province level in parenthesis.

Results in column 1 indicate that a one standard deviation increase in the SPI is associated with a decrease of out-migration by 1.97 thousand emigrants on average. This indicates that a drought, which represents a negative SPI shock, is associated with an increase of out-migration

Table 2: Baseline results for the impact of SPI shocks on out-migration

	<i>Outcome: Out-migration in thousand of emigrants</i>				
	Bivariate (1)	FE (2)	FE +controls (3)	FE (4)	FE +controls (5)
SPI	-1.97 (1.66)	0.01 (0.20)	0.20 (0.32)	–	–
SPI × Rural	–	–	–	-0.62** (0.27)	-0.49** (0.21)
SPI × Transitional	–	–	–	-0.38* (0.20)	-0.03 (0.19)
SPI × Urban	–	–	–	2.25 (1.60)	3.41 (3.02)
<i>Control variables</i>					
Primary education	–	–	-0.58 (0.45)	–	-0.54 (0.46)
Higher education	–	–	-1.24 (1.00)	–	-1.25 (1.00)
Sex ratio	–	–	-0.28 (0.17)	–	-0.28* (0.16)
Young population	–	–	1.31* (0.77)	–	1.34* (0.77)
Lagged population density	–	–	3.47*** (0.10)	–	3.49*** (0.13)
Constant	32.05*** (1.85)	28.53*** (0.77)	21.79 (21.26)	28.32*** (0.87)	21.07 (20.19)
Fixed effects	No	Yes	Yes	Yes	Yes
Number of observations	776	776	776	776	776
Number of provinces	71	71	71	71	71
Adjusted $R^2$	0.002	0.094	0.602	0.1	0.613

*Notes:* Results from linear regressions reported. *SPI* is the 12-month SPI per year and province. *Rural*, *Transitional* and *Urban* are indicator variables for rural, transitional and urban provinces, respectively. *Primary education* and *Higher education* are the share of population above 15 years with primary and higher education, respectively. *Sex ratio* is the ratio of male per female. *Young population* is the share of population between 15 to 24 years. *Lagged population density* is the population density in the previous year. The period of observation is from 2008 to 2018. In all columns we include province and year fixed effects, and report standard errors clustered at the province level in parentheses. \*,\*\* and \*\*\* respectively denote statistical significance at 10%, 5% and 1%.

on average. However, this coefficient is not statistically significantly different from zero, and introducing fixed effects and control variables considerably reduces the magnitude of the coefficient, making it slightly positive and still statistically insignificant (see Auffhammer and Vincent, 2012, for a similar result).

More interestingly, columns 4 and 5 show that decomposing the SPI coefficient across rural, transitional and urban provinces implies a negative and statistically significant effect of SPI shocks in rural provinces (p-val.<5%). Quantitatively, in the specification with control variables (col. 5), a 1 standard deviation *decrease* in the SPI *increases* out-migration in rural provinces by

0.49 thousand emigrants on average, which is around 3 percent of average yearly out-migration in rural provinces. In urban provinces, the coefficient associated with the SPI is positive although it is not precisely estimated, while in transitional provinces the coefficient is close to zero and statistically insignificant. Overall, these results suggest that drought (negative SPI shocks) increase out-migration in rural provinces, whereas a positive coefficient for urban provinces implies an average effect (col. 3) which is very close to zero.

### **3.3 Channels: GDP per capita, agricultural GDP per capita and conflict fatalities**

Table 3 reports our channel specifications using three alternative mediating variables: GDP per capita (columns 1 and 2), agricultural GDP per capita (columns 3 and 4), and conflict fatalities (columns 5 and 6). More specifically, columns 1, 3 and 5 report estimation results for the first step estimation (equation 3), which quantifies the impact of SPI shocks on each mediating variable. Then, columns 2, 4 and 6 report the second step of the channel analysis (equation 4), where we estimate the effect of SPI shocks on out-migration across our urban-rural classification of provinces, including the mediating variable as a control. In all columns we include province and year fixed effects, the full set of control variables, and report standard errors clustered at the province level in parenthesis.

Starting with GDP per capita, column 1 shows that the coefficient for the SPI variable estimated for rural provinces is positive and highly statistically significant ( $p\text{-val.} < 0.01$ ). This implies that, in rural provinces, negative SPI shocks are associated with a decrease in GDP per capita. This highly statistically significant relationship between SPI shocks and GDP per capita is a necessary condition for the mediated-moderator analysis (MacKinnon et al., 2007; Morgan-Lopez and MacKinnon, 2006). Furthermore, column 2 shows that the coefficient for GDP per capita is negative and highly statistically ( $p\text{-val} < 0.01$ ), which implies that a decrease in per capita income acts as a push factor in migration decisions, as expected. More importantly for our analysis, we highlight that the coefficient for the SPI variable in rural provinces is now significantly smaller in size as compared to the results in Table 2, column 5, and not statistically significantly different from zero any more. Taken together, these results show that GDP per capita fully mediates the impact of SPI shocks in rural provinces.



Table 3: Analysis of channels for the impact of SPI shocks on out-migration

<i>Specification:</i>	Channel: GDP		Channel: Ag. GDP		Channel: Conflicts	
	GDP p.c. (1)	Out-migration (2)	Ag. GDP p.c. (3)	Out-migration (4)	Conflicts (5)	Out-migration (6)
SPI × Rural	0.06 <sup>***</sup> (0.02)	-0.27 (0.19)	-0.02 (0.03)	-0.49 <sup>**</sup> (0.22)	-0.01 <sup>*</sup> (0.01)	-0.49 <sup>**</sup> (0.22)
SPI × Transitional	-0.03 (0.03)	-0.15 (0.17)	0.07 <sup>*</sup> (0.04)	0.01 (0.18)	0.01 (0.01)	-0.02 (0.19)
SPI × Urban	-0.32 <sup>***</sup> (0.10)	2.26 (2.73)	-0.07 <sup>***</sup> (0.02)	3.38 (3.01)	0.01 (0.01)	3.42 (3.04)
<i>Mediating variables</i>						
GDP per capita	–	-3.56 <sup>***</sup> (1.08)	–	–	–	–
Agricultural GDP per capita	–	–	–	-0.46 (0.48)	–	–
Conflict fatalities	–	–	–	–	–	-0.25 (1.65)
<i>Control variables</i>						
Primary education	0.03 (0.04)	-0.44 (0.36)	0.07 (0.06)	-0.51 (0.43)	-0.01 (0.01)	-0.55 (0.46)
Higher education	0.07 (0.07)	-1.02 (0.77)	0.11 (0.10)	-1.20 (0.95)	-0.06 <sup>**</sup> (0.03)	-1.27 (1.06)
Sex ratio	0.02 (0.02)	-0.21 (0.15)	-0.04 (0.03)	-0.30 <sup>*</sup> (0.17)	0.01 (0.01)	-0.28 <sup>*</sup> (0.16)
Young population	-0.15 <sup>**</sup> (0.06)	0.82 (0.61)	0.02 (0.09)	1.35 <sup>*</sup> (0.78)	0.04 (0.03)	1.35 (0.82)
Lagged population density	0.01 (0.01)	3.53 <sup>***</sup> (0.10)	-0.07 <sup>**</sup> (0.03)	3.46 <sup>***</sup> (0.13)	0.01 <sup>***</sup> (0.00)	3.49 <sup>***</sup> (0.14)
Constant	7.18 <sup>***</sup> (1.79)	46.61 <sup>*</sup> (24.23)	3.63 (2.26)	22.73 (21.03)	0.08 (0.52)	21.09 (20.33)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	776	776	776	776	776	776
Number of provinces	71	71	71	71	71	71
Adjusted $R^2$	0.78	0.64	0.71	0.61	0.09	0.61

Notes: Results from linear regressions reported. *SPI* is the 12-month SPI per year and province. *Rural*, *Transitional* and *Urban* are indicator variables for rural, transitional and urban provinces, respectively. *GDP p.c.* is per capita GDP, *Ag. GDP p.c.* is agricultural GDP per capita, and *Conflict fatalities* is the number of fatalities in conflicts (in hundred). *Primary education* and *Higher education* are the share of population above 15 years with primary or a higher education, respectively. *Lagged population density* is the population density in the previous year. The period of observation is from 2008 to 2018. In all columns we include province and year fixed effects, and report standard errors clustered at the province level in parentheses. \*, \*\* and \*\*\* respectively denote statistical significance at 10%, 5% and 1%.

Next, we consider agricultural GDP as an alternative channel in the relation between SPI shocks and out-migration, although results presented in column 3 show that SPI shocks are not found to have a statistically significant impact on agricultural GDP per capita. In line with this, introducing agricultural GDP per capita as a control variable in our main specification (column 4) does not affect the point estimate for the SPI variable, so that the coefficient remains very similar to that reported in column 5 of Table 2. These results suggest that agricultural GDP is not a mediating variable in the relationship between SPI shocks and out-migration in rural

provinces.

Lastly, column 4 provides evidence about the relationship between SPI shocks and conflicts, providing some evidence that an increase in SPI implies a decline in the number of fatalities in rural provinces (p-val.<0.1). However, using conflicts as mediating variable for our main specification (column 5), we find no statistically relationship between conflict fatalities and out-migration, and also no changes in our main estimate for the impact of SPI shocks on out-migration in rural provinces. Thus, while there is some evidence that drought events increase the propensity for conflicts in rural provinces, we do not find that conflicts act as a mediator in the relationship between SPI shocks and out-migration.

### **3.4 Robustness check**

Table 4 reports a set of robustness results focusing on how we measure shocks to rainfall in our main specification (equation 2). Results for 24-month SPI are in column 1, and those for 36-month SPI are in column 2. In column 3, we use our baseline 12-month SPI, and add a lag to the equation. In column 4 we employ an indicator variable for drought, which is equal to 1 when the 12-month SPI is equal or below -1, zero otherwise. In column 5 we use the same definition of a drought, but use a variable containing the number of successive years of drought. Lastly, column 6 uses average precipitations as an alternative to the SPI index. In all columns we include province and year fixed effects, the vector with all control variables, and report standard errors clustered at the province level in parenthesis.

Estimates in columns 1 and 2 of Table 4 show that using 24-month and 36-month SPIs generate qualitatively comparable patterns, with negative impacts on for rural provinces. However, point estimates are smaller and statistically insignificant. Similarly, introducing a lagged 12-month SPI (col. 3) does not affect the magnitude of contemporaneous effects, whereas the coefficients for the lagged variables are small and statistically insignificant. This suggests that a 12-month SPI captures relevant features in how rainfall shocks affect out-migration in rural provinces.

Columns 4 suggests that drought tend to increase out-migration in rural districts and reduce it in urban districts, which is again consistent with the main results. The magnitude of the

Table 4: Robustness results for the impact of alternative measures of rainfall on out-migration

<i>Outcome: Out-migration in thousand of emigrants</i>						
	24-month SPI (1)	36-month SPI (2)	Lagged SPI (3)	Drought (4)	Drought years (5)	Precipitation (6)
SPI × Rural	-0.127 (0.268)	-0.047 (0.303)	-0.485** (0.221)	–	–	–
SPI × Transitional	0.209 (0.236)	0.694* (0.397)	0.066 (0.188)	–	–	–
SPI × Urban	1.911 (1.603)	1.223 (1.223)	3.335 (3.013)	–	–	–
Lagged SPI × Rural	–	–	0.145 (0.274)	–	–	–
Lagged SPI × Transitional	–	–	0.039 (0.190)	–	–	–
Lagged SPI × Urban	–	–	-0.398 (0.539)	–	–	–
Drought × Rural	–	–	–	0.689 (0.952)	1.081 (0.667)	–
Drought × Transitional	–	–	–	-0.372 (0.612)	0.511 (0.572)	–
Drought × Urban	–	–	–	-4.829** (2.085)	-8.646 (7.700)	–
Precipitation × Rural	–	–	–	–	–	0.131 (0.154)
Precipitation × Transitional	–	–	–	–	–	-0.380* (0.222)
Precipitation × Urban	–	–	–	–	–	2.586 (2.262)
Constant	20.683 (20.539)	20.183 (20.988)	21.139 (20.158)	21.623 (21.633)	23.243 (21.152)	19.713 (19.925)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	776	776	776	776	776	776
Number of provinces	71	71	71	71	71	71
Adjusted $R^2$	0.604	0.603	0.613	0.602	0.609	0.612

*Notes:* Results from linear regressions reported. In column 1, *SPI* is the 24-month *SPI* per year and province, and in column 2 it is the 36-month *SPI*. In column 3 *SPI* is the 12-month *SPI* per province and the regression also includes its lagged value. In column 4 *Drought* is an indicator variable equal to 1 if the 12-month *SPI* is equal or smaller than -1, zero otherwise, and in column 5 it is the count of successive years in which the 12-month *SPI* is equal or below -1. *Precipitation* is the monthly average precipitation per year and province. *Rural*, *Transitional* and *Urban* are indicator variables for rural, transitional and urban provinces, respectively. The set of control variables is: *Primary education*, *Higher education*, *Sex ratio*, *Young population* and *Lagged population density* (see Table 1 for definitions). The period of observation is from 2008 to 2018. In all columns we include province and year fixed effects, control variables and report standard errors clustered at the province level in parentheses. \*, \*\* and \*\*\* respectively denote statistical significance at 10%, 5% and 1%.

coefficients increase when we consider the impact of successive years of drought (column 5). However, we note that the coefficients for rural districts is not statistically significant, which suggests that variability captured by the *SPI* variable cannot be summarized to a simple drought indicator. And in fact, using a raw measure of yearly average precipitation (column 6) yields a similar pattern of out-migration, although estimates are not precisely estimated. Overall, this set of results provides confidence in the relationship we estimate between the 12-month *SPI* and out-migration across our rural-urban classification of provinces.

We now turn to our second set of robustness checks, which focus on our rural-urban classi-

Table 5: Robustness results for rural classification, irrigation, and measures of migration

Outcome:	Out-migration in thousand of emigrants			Alternative measures of migration		
	Urban population (1)	Ag. labor (2)	Irrigation (3)	% out-migration (4)	ln(out-migration) (5)	Net-migration (6)
SPI	-0.359*** (0.130)	2.405 (1.519)	–	–	–	–
SPI × % urban	0.938*** (0.035)	–	–	–	–	–
SPI × ag. labor share	–	-7.019* (3.997)	–	–	–	–
SPI × Rural	–	–	-0.551** (0.251)	-0.088** (0.040)	-0.140** (0.068)	1.580** (0.767)
SPI × Transitional	–	–	0.130 (0.191)	-0.072* (0.042)	-0.042 (0.080)	0.788* (0.414)
SPI × Urban	–	–	6.075 (4.152)	0.089** (0.039)	0.316*** (0.070)	-2.125*** (0.730)
SPI × Rural × Irrigation	–	–	0.187 (0.157)	–	–	–
SPI × Transitional × Irrigation	–	–	-0.407 (0.361)	–	–	–
SPI × Urban × Irrigation	–	–	-4.768 (2.907)	–	–	–
Constant	15.739 (18.667)	20.947 (20.480)	19.333 (19.806)	10.320*** (1.988)	35.816*** (3.267)	-120.067*** (35.884)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	776	776	776	776	776	776
Number of provinces	71	71	71	71	71	71
Adjusted $R^2$	0.649	0.612	0.621	0.236	0.437	0.190

Notes: Results from linear regressions reported. In column 1 to 3 the dependent variable is out-migration in thousand of emigrants, in column 4 it is out-migration divided by provincial population, in column 5 it is the natural log of out-migration, and in column 6 it is net migration measured as the difference between in-migration and out-migration divided by provincial population. *SPI* is the 12-month SPI per year and province, *% urban* is the share of the population in cities with 300'000+ inhabitants, *Ag. labor share* is the proportion of the provincial labor force working in agriculture. *Rural*, *Transitional* and *Urban* are indicator variables for rural, transitional and urban provinces, respectively. *Irrigation* is the share of irrigated hectares in total cultivated hectares measured in 2003. The set of control variables is: *Primary education*, *Higher education*, *Sex ratio*, *Young population* and *Lagged population density* (see Table 1 for definitions). The period of observation is from 2008 to 2018. In all columns we include province and year fixed effects, control variables, and report standard errors clustered at the province level in parentheses. \*, \*\* and \*\*\* respectively denote statistical significance at 10%, 5% and 1%.

fication and alternative measures of migration. Results are reported in in Table 5. In columns 1 and 2, we interact the 12-month SPI with, respectively, the share of population living in cities with more than 300,000 inhabitants and the share of population working in agriculture. In column 3, we include an interaction between the share of irrigated land (measured in 2003) and the 12-month SPI. Columns 4 to 6 consider the impact of the 12-month SPI on alternative outcome variables. Specifically, we report results for out-migration as a share of total population (column 4), the natural log of out-migration (column 5) and the rate of net migration (column 6). All specifications include province and year fixed effects, control variables, and we report standard errors clustered at the province level in parenthesis.

In column 1, the main effect associated with the SPI variable is negative and highly statistically significant, which suggests that negative SPI shocks in a hypothetical province with no

population living in large cities would imply higher out-migration. This effect is highly statistically significant ( $p\text{-val.} < 0.01$ ). In addition, the interaction with the proportion of urban residents is positive, indicating that urban areas show the opposite effect, which again consistent with the analysis reported above. Comparable results emerge from column 2, as an increase in the agricultural labor share implies that SPI shocks have more negative impacts on out-migration, although results are less precisely estimated. Taken together, this suggests that results with our rural-urban classification are robust to alternative definitions. By contrast, controlling for irrigated areas (column 6) does not give rise to major differences with our baseline results. Specifically, estimates do suggest that more irrigated land implies smaller out-migration response to SPI shocks, so that irrigation acts as a buffer, although the effect is not statistically significant.

Lastly, alternative measures of migration largely confirm previous findings. First, when the outcome is measured as fraction of provincial population (column 4), the coefficients on the SPI variable suggest that a one standard deviation decrease in SPI increases out-migration in rural provinces by almost nine percent ( $p\text{-val.} < 5\%$ ). Similarly, the corresponding figure for column 5 is 14% ( $p\text{-val.} < 5\%$ ). In both specifications, there is also some evidence of positive and statistically significant effects in urban districts (although the fact that we only observe 5 urban districts should be kept in mind). Considering net-migration (column 6), we find that SPI shocks have a positive impact in rural provinces, implying that drought years are associated with an overall decline in net migration (the converse is true for urban provinces). This result is consistent with a decline in out-migration, and lends further support to our main findings.

## 4 Discussion and conclusion

In this study, we have quantified the relationship between variability in rainfall and out-migration, providing novel empirical evidence on how SPI shocks affect out-migration in Turkish provinces. We have shown how the relationship is moderated by a rural to urban classification of provinces, and we have documented the mediating role of per capita GDP as a channel to explain higher out-migration as a response to negative SPI shocks in rural provinces. Intuitively, our data suggest that negative SPI shocks in rural provinces induce a decrease in per capita GDP, which in

turn acts as a push factor in out-migration decisions.

By contrast, we find little evidence about the role of agricultural GDP per capita or conflict fatalities. These results contrast with evidence from other contexts emphasizing the importance of agricultural output in migration decisions (Feng et al., 2010; Cai et al., 2016) or linking droughts with conflicts (Kelley et al., 2015; Missirian and Schlenker, 2017), and highlights the role of contextual and institutional factors climate-migration linkages (see also Abel et al., 2019). In the case of Turkey, a middle income country, one could hypothesize that the share of agriculture (6.5% in 2018) is too low to have economy-wide impacts, while the main armed conflict (Kurdish-Turkish conflict) may be more impacted by political endeavors rather than climatic variability. Alternatively, it may be that climate shocks have a wide impact not limited to the agricultural sector alone. This could reflect close interdependencies between economic activities directly impacted and the local economic system as a whole.

Nevertheless, our results do suggest that more frequent drought may increase out-migration from rural areas through economy-wide impacts. However, data on destination is necessary to understand whether this would hasten urbanization, lead to rural-rural displacements, or induce international migration. Developing our understanding in these migration patterns and design appropriate policies to support climate change adaptation remains an important research endeavor.

## Appendix A Rural-urban classification

Table A1: List of variables used in Oğdül (2010) six-factors analysis

Categories	Variables
Agricultural production	Percentage of agricultural production in percentage of total agricultural production Agricultural production values per 1000 rural residents Agricultural production values per 1000 people engaged in agriculture
Non-agricultural production	Level of non-agricultural production Employment in industrial sector per total employment Employment in construction sector per total employment Employment in commercial sector per total employment Employment in transportation sector per total employment Employment in finance sector per total employment
Employment structure	Employee per total employment Women employee per total employment Employers per total employment Dependency ratio
Demography	Population size Rate of urbanization Population density
Educational level	Literate per total population Literate women per total women population Higher education graduates per total population Service zone grade for civil servants in education and academics
Trade opportunities	Accessibility (availability of airports, ports and railways) Budget income per capita Number of branch banks

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