Extreme Temperatures and Internal Migration: Evidence from China *

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Abstract

This paper investigates the impacts of extreme temperatures on internal migration in China from 1995 to 2010, employing county-level data for analysis. The findings reveal a significant migrate-out effect from counties experiencing extreme low temperatures; specifically, an additional day with temperatures below 10°F increases net outmigration by 0.073 percentage points compared to a day with temperatures ranging between 50-60°F. Conversely, increased temperature act as a deterrent to migration, with male outmigration showing a significant decrease under extreme high temperatures (>90°F). This divergence in response to extreme temperatures is postulated to stem from variations in perceptual abilities. Intriguingly, female migrants display a distinct pattern, remaining unaffected in their migratory responses to both extreme high and low temperatures. This deviation may be attributed to entrenched traditional Chinese ideologies influencing female mobility. Further investigation into rural regions and agricultural growing seasons yields results consistent with the baseline results, with a more pronounced effect from high temperatures, thereby providing a suggestive evidence of potential liquidity constraints based on the agricultural mechanism, suggesting that the financial hardships from failed agricultural outputs can act as a barrier, preventing individuals from migrating even if they are motivated to do so.

Keywords: extreme temperatures, internal migration, rural regions, growing seasons, liquidity constraint

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1 Introduction

Concerns are growing over the rising temperatures attributable to excessive greenhouse gas emissions. Global warming, a pressing issue demanding immediate attention, exerts profound effects on our environment. These effects range from rising sea levels and increasingly severe weather patterns to shorter cold seasons. Beyond environmental impacts, high temperatures also profoundly affect humans, both mentally (Mullins and White, 2019) and physically (Yu et al., 2019). Human migration, a significant phenomenon with considerable implications for urbanization (Henderson et al., 2017) and population redistribution (Rees et al., 2017), emerges as a critical area of study in this context. This paper specifically delves into the influence of extreme high temperatures on internal migration in China, unraveling the mechanisms underlying this relationship.

To empirically investigate the impact of extreme temperatures on migration patterns, I utilize a comprehensive dataset combining county-level migration information and temperature data. [1] The migration data, structured as a county-year-level panel, is derived from the China Statistical Yearbook for the years 1995, 2000, 2005, and 2010. Concurrently, I incorporate temperature data calculated from station- and daily-level weather observations collated by the National Oceanic and Atmospheric Administration (NOAA). A crucial aspect of the migration data is its time span of the 5-year net outmigration between the specified years, necessitating a corresponding 5-year span for the temperature data. This alignment ensures consistency in the data, enabling a robust analysis of the intricate relationship between extreme temperatures and migration patterns.

In this study, I employ a two-way fixed effects model to explore the relationship between a county's net outmigration rate and temperature, categorized into various bins. The model controls for county and year fixed effects, as well as a flexible function of other time-varying weather variables. The findings indicate a pronounced positive effect of extreme low temperatures on the county's net outmigration ratio. Specifically, an additional day with temperatures below 10°F results in a 0.073 percentage point increase in net outmigration, compared to days with temperatures ranging from 50-60°F.[2] Conversely, the outmigration of males is significantly

[1] In China, the highest administrative division level is province-level, followed by prefecture-city-level and county-level.

[2] In this study, temperature intervals below 10°F and above 90°F are defined as extreme low and high temperature ranges, respectively. The 50-60°F range serves as the omitted reference group.

reduced under extremely high temperatures. The observed divergence in migratory responses to extreme temperatures is hypothesized to arise from differing perceptual abilities. Specifically, the subtle and cumulative impact of extreme heat may obscure its harmful effects, trapping economically strained individuals at their origin due to prohibitive migration costs. Furthermore, no substantial migratory responses to extreme temperatures were observed among females. The diminished male outmigration under high temperatures raises the possibility of a ”liquidity constraint,” suggesting that financial difficulties stemming from unsuccessful agricultural endeavors could hinder individuals from migrating.

To further investigate the “liquidity constraint” hypothesis, I narrow the focus to rural counties, finding results consistent with the full sample. The contrasting migratory reactions to extreme low and high temperatures, observed in overall outmigration patterns, persist and can be attributed to differences in perceptual abilities. Gender-specific analysis within rural areas reveals that extreme high temperatures have a more pronounced negative impact on male outmigration compared to the full sample. Additionally, rural males are more inclined to migrate under moderate temperatures than their female counterparts, a trend potentially attributable to traditional Chinese ideologies and supported by findings from other empirical studies.

To corroborate the agricultural influence, I calculate temperature exclusively during the agricultural growing seasons, following the categorization established by Deschênes and Greenstone (2007), which is applicable to the majority of crops.[3] The results closely align with those from the previous rural sample analysis. While extreme low temperatures have no significant impact on overall rural migration—likely due to their rarity during growing seasons—the restraint of extreme high temperatures on rural male outmigration is even more salient. Female outmigration remains suppressed during moderate temperature days, corroborating the realities observed in China that males—often the familial providers, particularly in impoverished areas—may migrate in search of economic stability, leaving behind spouses and children. This consistency lends further support to the previous hypothesis, suggesting that “liquidity constraints” resulting from agricultural challenges can indeed serve as a significant obstacle to migration, even when the desire to relocate is present.

This paper makes multiple contributions to the existing body of literature. The concept of

[3] The period from April to September is designated as the growing season, while the remaining months are considered the non-growing season, in accordance with Deschênes and Greenstone (2007).

"environmental refugees," as introduced by Myers (1997), has sparked a plethora of empirical research. Such research predominantly focuses on the involuntary migration triggered by adverse climate anomalies, encompassing both internal (Gray and Mueller, 2012; Marchiori et al., 2012; Mueller et al., 2014; Bohra-Mishra et al., 2014; Jennings and Gray, 2015; Mastrorillo et al., 2016) and international movements (Reuveny and Moore, 2009; Beine and Parsons, 2015; Cai et al., 2016). Additionally, some scholars have unearthed the heterogeneous effects of climate anomalies, noting variations across different regions (Gray and Wise, 2016; Thiede et al., 2016) and among various migrant demographics (Dillon et al., 2011; Gray and Mueller, 2012; Mastrorillo et al., 2016). Intriguingly, there are instances where these climate impacts appear to be negligible, resulting in a null effect within certain contexts (Gray and Bilsborrow, 2013; Henderson et al., 2017; Liu, Shamdasani and Taraz, 2023). A minority of studies have also illuminated the existence of a "liquidity trap" in impoverished nations (Cattaneo and Peri, 2016; Nawrotzki and Bakhtsiyarava, 2017). These works suggest that the increasing temperature may actually diminish the likelihood of emigration—whether to urban centers or other countries—due to resource constraints. This phenomenon challenges the narratives that imply a consistent migratory response to climate change. Despite these extensive investigations, the academic community has yet to converge on a unified theory that encapsulates the complex relationship between climate change and human migration.

The most recent comprehensive analysis of these varied findings is provided by Cattaneo et al. (2019), who assert that individuals or households resort to migration only when alternative adaptation strategies—encompassing both on-farm and off-farm adjustments—fall short. Despite this, few research has been conducted to ascertain the presence of migration responses to climate anomalies, as well as the existence of a "liquidity trap" in relatively affluent developing countries, where a plethora of adaptation alternatives are available to bolster the adaptive capacity of potential migrants. As the world's largest developing economy, contributing significantly to global CO_2 emissions, China presents a unique context for such an investigation. Nevertheless, there is a noticeable paucity of literature addressing this issue within the Chinese context. By integrating census data from China with NOAA weather data, this paper endeavors to bridge this research gap, offering valuable insights into the complex interplay between climate anomalies, adaptive strategies, and migration patterns in a developing country setting.

This paper selects China as the focal point of investigation for three reasons. Firstly, rural inhabitants are particularly susceptible to vulnerability, stemming from prevalent poverty (Foresight, 2011; Black et al., 2011) and constrained access to adaptive strategies, such as air-conditioning (Brooks et al., 2005; Feng et al., 2010; Hu and Li, 2019). The *Hukou* system in China distinctly categorizes households as either rural or urban, ensuring a clear demarcation between these two regions. [4] Secondly, existing literature predominantly postulates agriculture as the primary channel through which climate anomalies impact human mobility (Fischer et al., 2005; Feng et al., 2010; Cai et al., 2016). In this scenario, those individuals and households with incomes tied, either directly or indirectly, to agriculture are most susceptible to income volatility. Adverse climate events, potentially leading to diminished agricultural yields, may compel rural inhabitants or specific household members to seek migration as a means of livelihood (Cattaneo et al., 2019). Supporting this, Chen et al. (2016) unveil the considerable economic losses incurred by China's corn and soybean sectors over the past decade due to global warming, thereby highlighting a tangible agricultural channel for investigation in this paper. Lastly, China's expansive territorial expanse results in a diverse climate with four distinct seasons, creating substantial temperature variations across different regions. Furthermore, the nation's susceptibility to climate change has been well-documented (Piao et al., 2010; Zhao et al., 2016), providing a robust framework to examine the effects of extreme high temperatures.

While Gray et al. (2020) provide an insightful analysis of the long-term trends in the climate-migration relationship within China, their work primarily centers on broader tendencies. In contrast, this paper delves deeper, aiming to scrutinize the presence of a liquidity trap and to explore the diverse migratory responses to extreme high temperatures specifically in the Chinese context. Unlike previous studies, such as those by Giles and Yoo (2007), Ward and Shively (2015), and Minale (2018), this research employs a comprehensive dataset that encompasses nearly all provinces in China, spanning across three distinct time periods (1995-2000, 2000-2005, 2005-2010). This extensive coverage ensures that the findings of this study offer a more representative and nuanced understanding of the migration patterns in relation to extreme temperature events.

The rest of the paper is organized as follows. Section 2 describes the data source and summary statistics. Section 3 presents the econometric model. Section 4 presents the main estimates of the effects of high temperatures on migration. I conclude in Section 5.

[4] *Hukou* is a household registration system in China. Households are classified as rural or urban type. Individual with rural *Hukou* cannot enjoy the public welfare in urban areas, such as schools, hospitals, and public sector jobs.

2 Data sources and summary statistics

To identify the impact of extreme temperatures on internal migration within China, I collecte data from multiple sources, including station-level weather data as well as county-level migration data. This section provides a comprehensive description of the datasets used in this study, along with a presentation of the summary statistics to offer a preliminary overview of the data characteristics.

2.1 Weather data

The weather data comes from the Global Historical Climate Network (GHCN) which is drawn from the National Oceanic and Atmospheric Administration (NOAA). The data reports station-level daily maximum temperature, daily minimum temperature, daily average temperature and daily average precipitation, which is captured by roughly 300 weather stations during 1995-1999, 2000-2004 and 2005-2009 (5 years before each study year). To capture the extreme temperature sufficiently, I use the daily maximum temperature to compute the the temperature days. The precipitation is defined as the total of all 5-year precipitation.

For more accurate temperatures of each county, I transform weather data from station- to county-level by using an inverse-distance weighting method. For each county, I assign the weather stations which locate within a 100 km radius of the county's centroid which is defined as the county's administration center. The weights are defined as the inverse straight-line distance between each station and the county's centroid. To avoid the contamination of missing value and keep a continuous weather recording when using daily-level data (Auffhammer et al., 2020), I only keep the stations with all valid recordings in a year (following Zhang et al. (2018)).

Schlenker and Roberts (2009) find serious nonlinear effect of high temperatures on the crop yield. Therefore, the effect of extreme temperature on migration through the agricultural channel should also be nonlinear. Following Deschênes et al. (2009) and Zhang et al. (2018), I discretize the annual distribution of daily temperatures into several fixed set of temperature bins to capture this nonlinear effect.

Specifically, each county's annual distribution of daily temperature (in °F) is divided into 10 bins, T_{ct}^{j}, where $j = 1, 2, ..., 10$. T_{ct}^{j} is the number of days in period t experienced by county c with daily temperature which locates in bin j. When $j = 1$, the related temperature bin is $< 10°$F. When $j = 10$, the temperature bin is $> 90°$F. For the rest interior bins, the width is $10°$F. Fig. 2 plots the time trend of yearly average temperature across all counties. The general trend of average temperature is increasing during the study period, though with some fluctuations.

2.2 Migration data

Based on the discussion of *Hukou* in Section 1, there are two types of migration in China according to the possession of local *Hukou*: floating migration and permanent migration. People who leave their origin place and migrate to a new county without changing to the new local *Hukou* are defined as floating migrants; people who migrates to a new county and possess the local *Hukou* status are defined as permanent migrants or registered migrants. In this paper, both types of migrants are included.

The county-level migration data are calculated from China Statistical Year book in 1995, 2000, 2005, and 2010. This paper focuses on the internal migration in China, so the international migration is not considered. [5]

The measurement for migration is the net outm igration ratio, which is defined as the percent of population leaving the county net of new arrivals and death. However, the death counts are not reported in the Statistical Yearbook. Chen et al. (2016) using the same study period find that the measurement error from using the imperfect net outmigration measures is minimal and statistically undetectable. Therefore, the death is considered in the calculation of net outmigration ratio. I use the residual approach to calculate the net outmigration rate following Feng et al. (2010), Feng, Oppenheimer and Schlenker (2015), and Chen et al. (2016). Specifically, the net outmigration rate over the 5-year period is calculated using the following equation:

$$NetOutmigration_{c,t} = \frac{Population_{c,t} - Population_{c,t+5}}{Population_{c,t}} \tag{1}$$

where $NetOutmigration_{c,t}$ is the net outmigration rate for county c from year t to year $t+5$ ($t = 1995, 2000, 2005$); $Population_{c,t}$ denotes the population in county c at the beginning of the five-year interval year t; and $Population_{c,t+5}$ indicates the population at the end of the five-year interval year $t+5$.

[5] The mean of international immigration rates in 1990 and 2000 is only 0.0058% (calculated from Population Census data), which contributes very little proportion to overall immigration rates.

Table I presents mean and standard deviation of the net outmigration rate and its heterogeneity among different gender. The mean of net outmigration for all periods is -6.42 percent. The sign of net outmigration rate could be positive or negative. The negative sign indicates most counties with less population are experiencing net inflows. Across all the three periods, the mean of net outmigration is increasing. This could be driven by the great economic development of some regions, such as Yangtze River delta, Pearl River Delta and some special economic zones. What is also striking is that the standard deviation of net outmigration is large which means there exists great heterogeneity of migration flows across counties. This could also be noticed from Fig.1. In Fig.1, most counties' net outmigration rate is positive. The counties which locate near the coastal areas have the negative ratio, which indicates there exists migration inflows in these counties, which coincides with the previous hypothesis. Also, most inland counties have migration outflows. This spatial heterogeneity is controlled in the model to make a clean identification. Lastly, I winsorize the data based on net outmigration rates at cut 1th and 99th percentiles to avoid the influence of extreme outmigration.

3 Econometric model

To empirically test the causality of high temperature on migration, I estimate the following two-way fixed effects model:

$$M_{ct} = \sum_{j=1}^{9} \beta^j T_{ct}^j + f(\mathbb{W}_{ct}) + \lambda_c + \gamma_t + \alpha_c t + \varepsilon_{ct} \tag{2}$$

where M_{ct} captures the outcome of interest, net outmigration rate, which is the fraction of people leaving a county minus new arrivals, in county c and period t. Each period is a 5-year interval. Thus, there are 3 periods: 1996-2000 (period 1), 2001-2005 (period 2), and 2006-2010 (period 3).

The variables of interest, T_{ct}^j, is the measures of temperature exposure in each predetermined temperature bins ($<$ 10°F, 10-20°F, ... , 80-90°F, $>$ 90°F) in the same county c. The variable, T_{ct}^j, is also five-year period, which is consistent with the dependent variable. My coefficient of interest β^j is the marginal effect of an extra day with temperature in bin j relative to a day in the reference temperature bin between 50-60°F, which is omitted from equation (2). Thus, in equation (2), $j = 1, 2, ..., 9$.

$f(\mathbb{W}_{ct})$ is a flexible function of weather variables.[6] The county fixed effects, λ_c, captures fixed county characteristics such as the geography, local culture and some other unobservable characteristics. The term γ_t is the year fixed effects, which represents for annual shocks which are common across counties, such as some national wide economic policy or restriction on migration. Since this study is over the period of the considerable structural transformation in China, facing a large rural-urban migration trend, a county-specific time trend, $\alpha_c t$, is also included to control for different outmigration growth potential. The last term ε_{ct} in equation (2) is the error term. To ensure the potential serial correlation, standard errors are clustered at county level. I also try to cluster standard error at prefecture level for robustness check. Conditional on various controls and fixed effects, the identification of β^j relies on the exogenous year-to-year variation of temperature within a county.

4 Results

4.1 Main results

I begin by presenting the baseline regression results estimated using equation (2). To elucidate these findings, Fig. 3 illustrates the response function between temperature days and the outcome variables: overall, male, and female net outmigration rates. The point estimates are represented by a blue line with dots, accompanied by the associated 95% confidence intervals for β^j in each bin. These estimates are provided for various temperature bins in degrees Fahrenheit, taking the daily temperature range of 50–60°F as the omitted reference group.[7]

Panel A of Fig. 3 delineates the relationship between temperature and net outmigration for the entire sample, revealing a generally decreasing trend. The coefficient for the extreme low temperature group is both positive and statistically significant, indicating that an additional day with temperatures below 10°F increases net outmigration by 0.073 percentage points, relative to a day in the 50–60°F range. This finding suggests a migrate-out effect, possibly corroborating earlier discussions on the detrimental impacts of extreme temperatures on agricultural

[6] Gray and Wise (2016) find the predominant effect of climate anomalies on migration comes from precipitation and temperature, so precipitation is controlled here.

[7] Given that $\sum_{j=1}^{10} \beta^j T_{ct}^j = 365$ for each county c in period t, I omit the 50–60°F group from the model to prevent multicollinearity, following Zhang et al. (2018).

output, prompting population movement. However, the net outmigration effect of extreme high temperatures is negative and not statistically significant in this comprehensive sample.

Analyzing gender-specific heterogeneity (Panel B and C of Fig. 3), I observe no clear effects from extreme low temperatures on either male or female migration outflows. Notably, in Panel B (the male group), the coefficient changes from positive to negative when transitioning from moderate (30–40°F, 40–50°F) to higher temperature intervals (60–70°F, 70–80°F). Additionally, extreme high temperatures (> 90°F) significantly inhibit male net outmigration, with a magnitude surpassing other temperature intervals. Meanwhile, the female group does not exhibit a significant migratory response to extreme high temperatures. These results imply that while males tend to migrate out during moderate temperatures, their mobility is significantly reduced under extremely high temperatures.

The observed pattern, especially for males, may be attributed to the "liquidity constraint" within the agricultural mechanism. This is supported by empirical evidence suggesting that rising temperatures can detrimentally affect crop yields, leading to income shocks and, consequently, restricted mobility for those reliant on agriculture (Carter et al., 2018; Ortiz-Bobea, 2021).

Considering that rural areas in China typically experience higher migration outflows and acknowledging the agricultural mechanism's dependence on the availability of farmland, I narrow the analysis to rural regions in the subsequent section, aiming to discern whether the effects of extreme temperatures are indeed mediated through agricultural channels.[8]

4.2 Results for rural areas

In this section, the analysis is narrowed down to rural areas to scrutinize the agricultural mechanism.[9] Drawing from the discussions in previous sections, I hypothesize that migratory responses to extreme temperature variations should be observable in rural areas if the agricultural mechanism is indeed the primary mechanism. The findings presented in Fig. 4 corroborate

[8]The data in this paper confirms that rural areas exhibit a relatively larger net outmigration rate than urban areas (-6.16% vs. -6.69%), validating this assumption.

[9]A rural county is defined here as one whose total population falls below the median.

this hypothesis.[10]

Panel A of Fig. 4 delineates a decreasing trend analogous to that observed in the baseline results, with a pronounced positive response of outmigration to extreme low temperatures, exhibited at a greater magnitude. The coefficient associated with extreme high temperatures remains negative, albeit non-significant; however, its magnitude is somewhat larger in this context.

Moving to Panel B, it can be observed that the relationship between temperature and male outmigration in rural areas is consistent with the baseline results (as depicted in Panel B of Fig. 3). The trend of transitioning coefficients with increasing temperatures is retained, and the restraining effect of extreme high temperatures on male outmigration is more pronounced in rural areas (-0.136) compared to the full sample (-0.114). In contrast, female migratory responses to extreme temperatures in rural areas do not show any significant variation.

Intriguingly, the comparison between Panel B and C suggests that female migration is more likely to be suppressed than male migration at moderate temperatures (30-80°F). This aligns with the findings of Ahmed and Kiester (2021), who report that female-headed farms are less inclined to sell their farmland or migrate in pursuit of non-farm income, attributed to gendered societal expectations and cultural constraints.

Additionally, perceptual abilities play a pivotal role in explaining the two opposite reaction to extreme low and high temperature. Individuals can readily discern extreme cold, whereby they may take some avoidance behaviors to prevent the extreme low temperature's deleterious effect on crops. Feng, Oppenheimer and Schlenker (2015) contend that adaptive measures are predominantly undertaken when high temperatures breach perceptual thresholds. In instances of extreme cold, the tangible coldness, coupled with potential agricultural damage, may prompt individuals to abandon agrarian livelihoods and migrate. Conversely, the insidious nature of extreme heat may veil its detrimental effects, trapping economically strained individuals at their origin due to prohibitive migration costs.

[10]Results pertaining to urban regions are illustrated by Fig. A.1 in the Appendix. Across various samples—overall, male, and female—there are no statistically significant migratory responses observed in relation to either extreme low or high temperatures. Notably, the coefficient corresponding to extreme high temperatures within the urban male subgroup is negative and significant. However, it is crucial to highlight that the associated p-value stands at 0.032, which is higher than the p-values observed in rural areas and full sample. Consequently, the findings from the urban sample do not undermine the conclusions drawn in this paper.

4.3 Results for growing seasons

Agronomists propose that plant growth is contingent upon cumulative exposure to heat and precipitation throughout the growing season. Consequently, I delineate the period from April 1 to September 30 as the growing season in alignment with Deschênes and Greenstone (2007), capturing the critical growth phases for a majority of crops, excluding winter wheat (United States. National Agricultural Statistics Service, 1999). Owing to the rarity of county-level temperatures falling below 10°F, I combine the temperature intervals <10°F and 20-30°F into a single category, <20°F, to mitigate multicollinearity concerns.

The adaptation of degree day calculations to exclusively encompass growing seasons lays a more robust groundwork for exploring the agricultural channel. Fig. 5 elucidates the impact of growing-season temperatures on rural area net outmigration. Panel A, focusing on overall rural outmigration, reveals a lack of significant migration in response to extreme low temperatures, a likely consequence of the infrequency of such temperatures during the growing seasons. Nevertheless, the signs of coefficients for extreme low and high temperatures aligns with our preliminary hypotheses.

In Panel B, the extreme high temperature's restraint on male outmigration remains significant, and with an even larger magnitude. This panel also captures some degree of rural male outmigration to moderate temperature during growing seasons. In Panel C, the effects of extreme high and low temperatures are still insignificant on rural female outmigration in response to growing season temperatures. And the female's shackled outmigration during moderate temperatures days persists the stark contrast with the situations in male group.

The observed gender-specific heterogeneity may stem from entrenched ideological norms in the context of China. In scenarios where moderate temperature causes decent agricultural income for individuals to afford the migration cost, males—often the familial providers, particularly in impoverished areas—may migrate in search of economic stability, leaving behind spouses and children. This phenomenon, prevalent in China, has led to the colloquial designation of such individuals as "rural migrant workers in cities."

To sum up, the pronounced inhibiting impact of extreme high temperatures during growing seasons on rural male net outmigration underscores the concept of "liquidity constraint." This phenomenon suggests that when temperatures soar to extreme levels, leading to crop failures, the resulting economic shock could hinder potential migration motivations. Essentially, the financial hardships from failed agricultural outputs can act as a barrier, preventing individuals from migrating even if they are motivated to do so. This finding adds a critical dimension to our understanding of the intricate relationship between climate change, agriculture, and human migration patterns.

5 Conclusions

The raising temperatures have gained significant attention, particularly regarding their detrimental impacts on human society. Prior research has demonstrated that prolonged exposure to extreme high temperatures can profoundly affect agricultural productivity, which serves as the primary livelihood for many farmers. However, the resulting crop failure can simultaneously act as a catalyst, motivating farmers to abandon their land in search of better opportunities elsewhere, while also diminishing their financial capacity to bear the costs of migration. Leveraging the rise in temperatures as a source of exogenous variation, this paper aims to explore the effects of increasing temperatures on internal migration patterns, providing empirical insights to enhance our understanding of this complex issue.

The findings presented in this paper highlight a significant trend of outmigration in response to extremely low temperatures ($<$10°F). In contrast, male outmigration tends to be inhibited by extreme high temperatures ($>$90°F). This divergence in migratory behavior between low and high temperatures may be rooted in differing perceptual abilities. Interestingly, the result does not indicate a significant migratory response from females in the face of either temperature extreme. Traditional Chinese ideologies appear to offer a plausible explanation for the observed gender disparities in migration responses. Further analysis focusing on rural regions and temperatures on agricultural growing seasons reveals a pattern consistent with the baseline results. This consistency provides a suggestive evidence to the liquidity constraint hypothesis, suggesting that financial difficulties stemming from poor agricultural yields can create a formidable obstacle, deterring individuals from migrating despite their willingness to relocate.

Finally, it is important to point out the limitations of the paper. Given the considerable structural transformation occurring in China during the study period, there is a huge amount of migrant workers moving from rural to urban regions. While some male outmigration is found in days with moderate temperatures (30-80°F), it remains ambiguous whether this outmigration is driven by the allure of larger cities, the "pull" factor, or whether it is instigated by specific circumstances at their places of origin, constituting a "push" factor.

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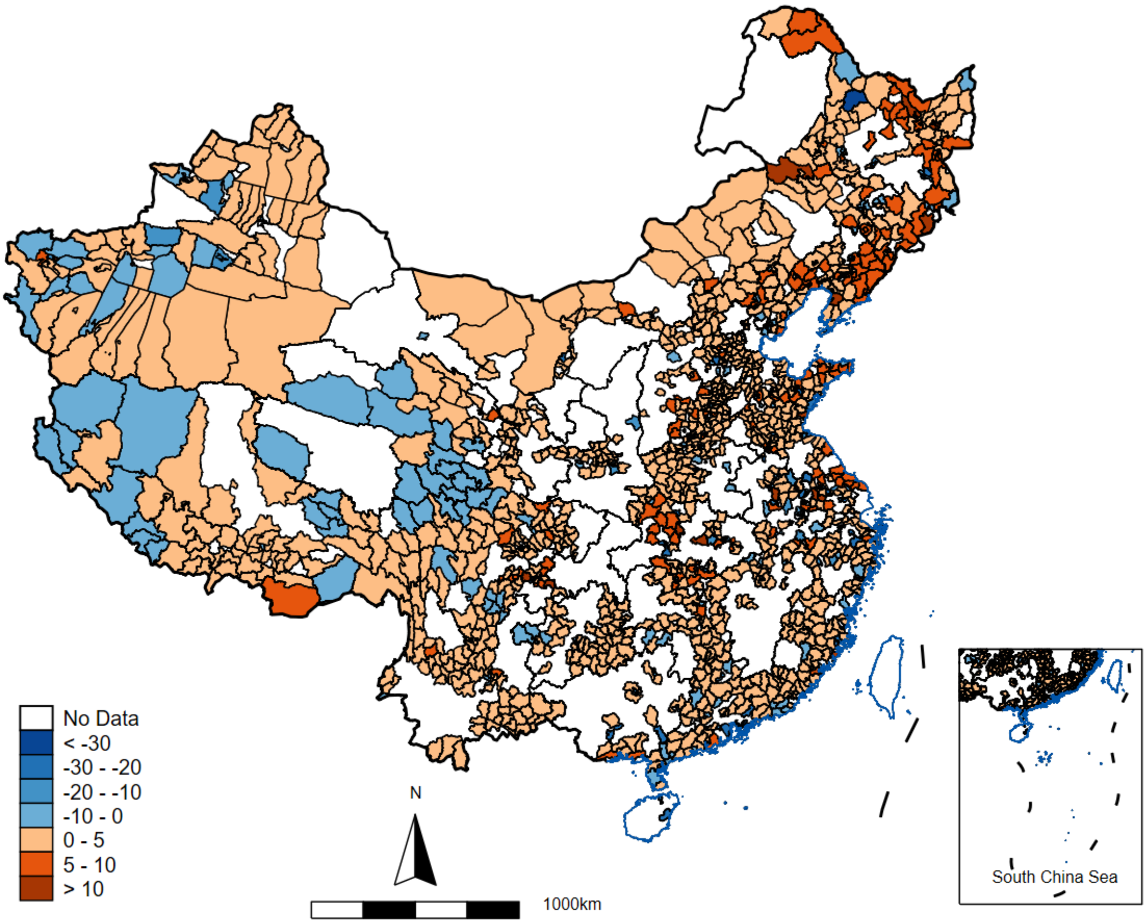
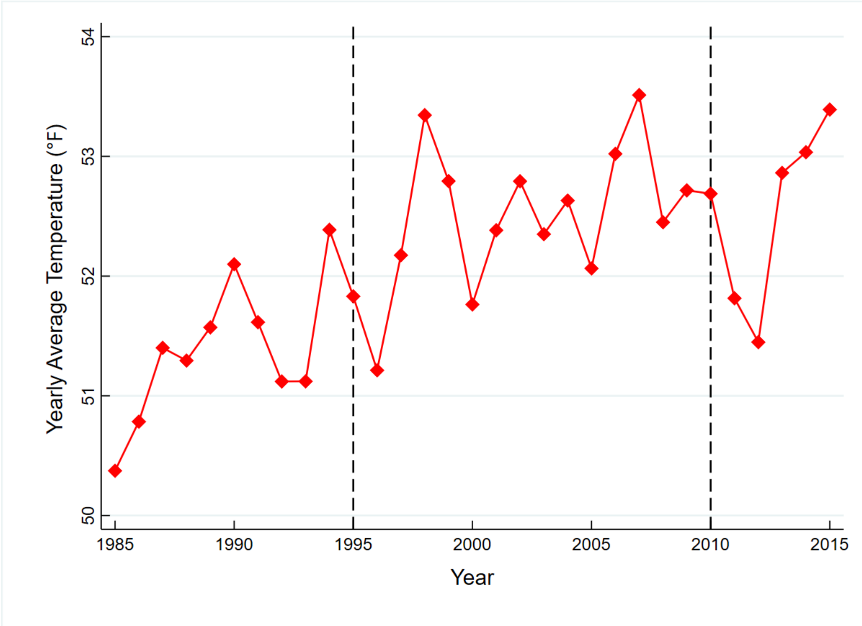
Figures and Tables

Figure 1: Net Outmigration Rate (%) in China (1995-2010)



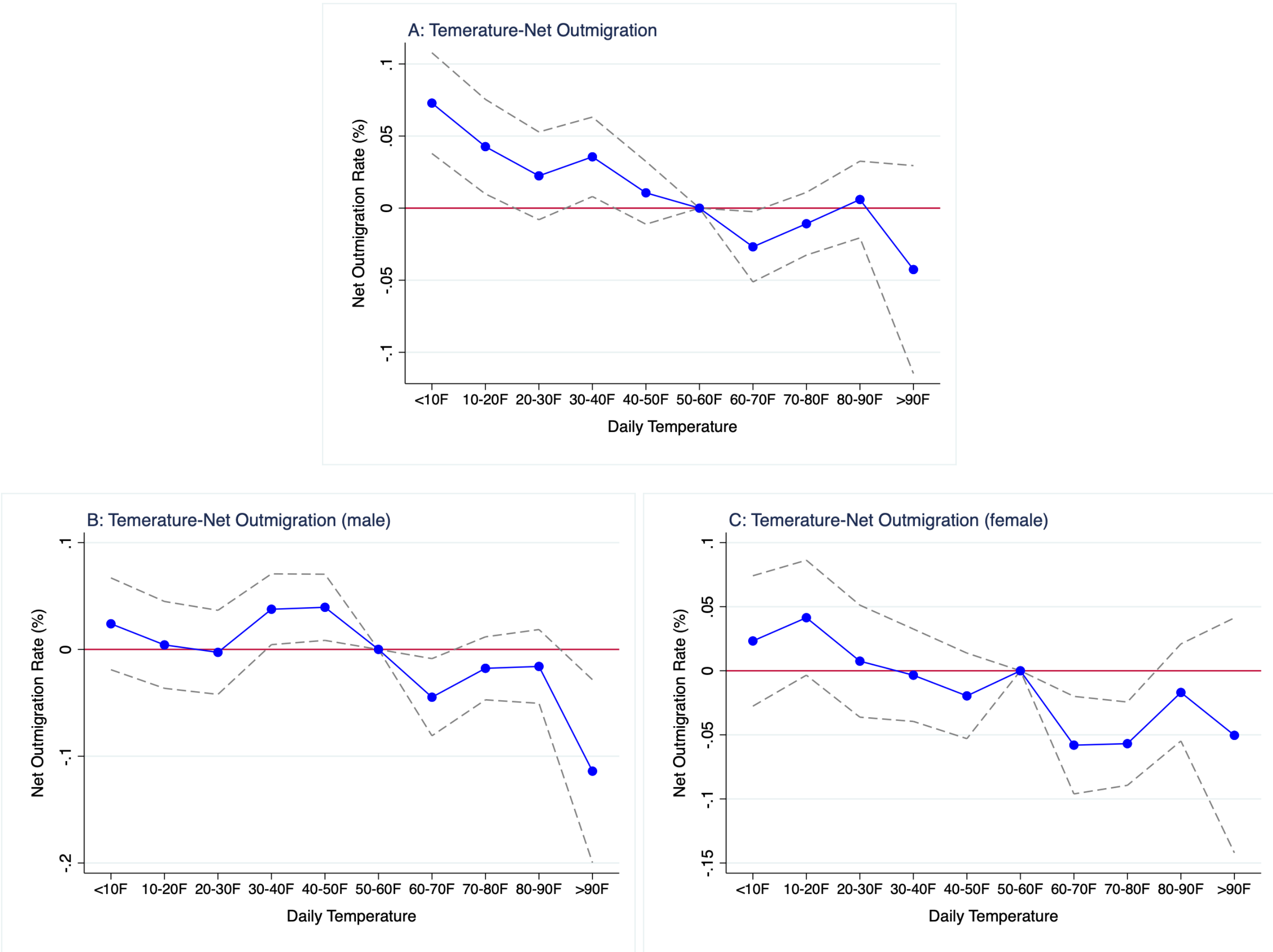
Notes: This figure depicts the average migration for each county in China over the period 1996-2010. Migration is measured by net outmigration rate, which is the percent of population leaving the county net of new arrivals. Negative sign means there is outmigration for the county during the 5 years in total. The opposite case means the in-migration.

Figure 2: Time Trend of Yearly Average Temperature in China (1985-2015)



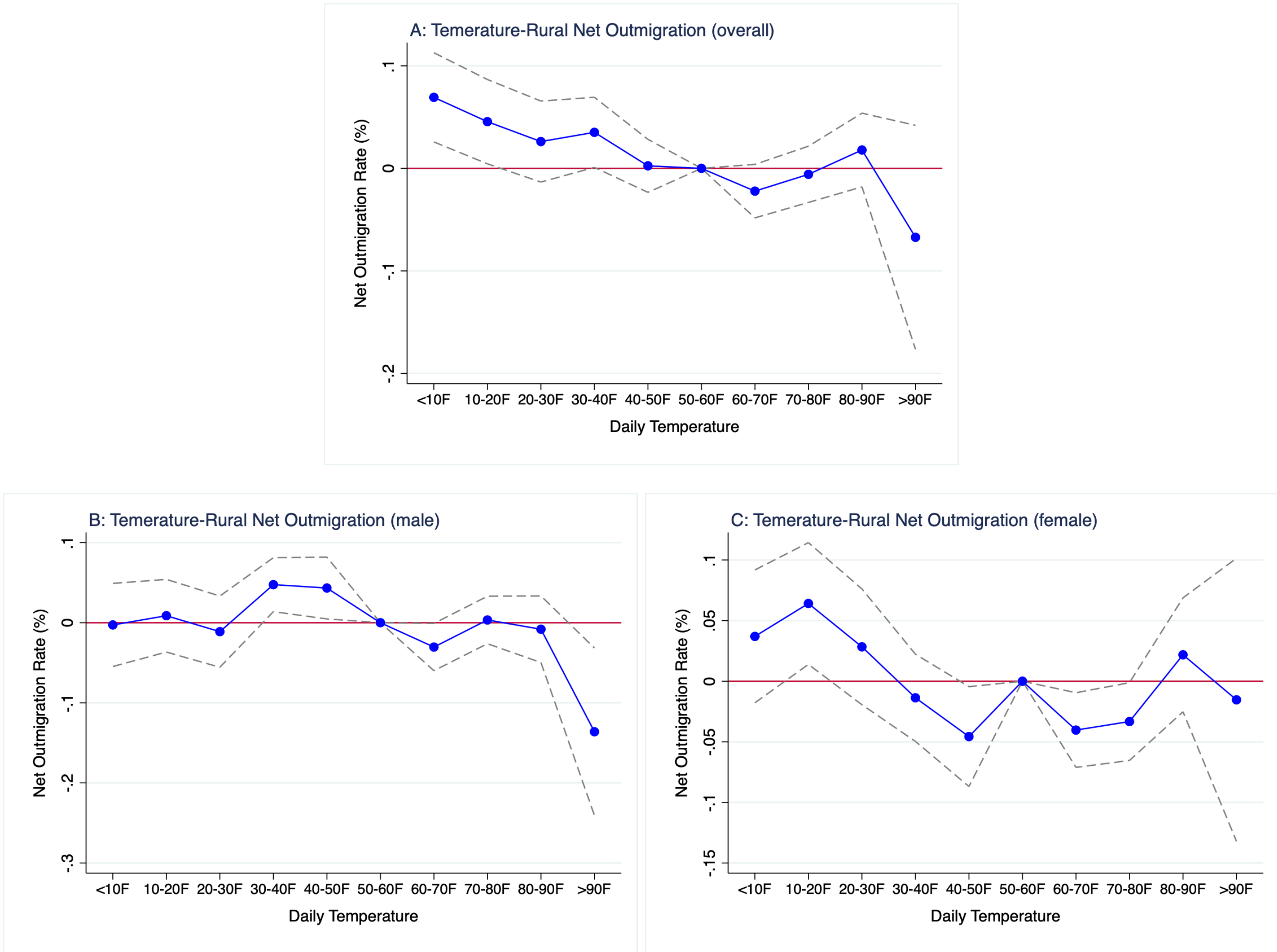
Notes: This figure plots the time trend of yearly average temperature in China over period 1985-2015. Two vertical dashed lines highlight the study period 1995-2010.

Figure 3: Estimated Effects of Daily Temperature on Overall, Rural, Male and Female Net Outmigration



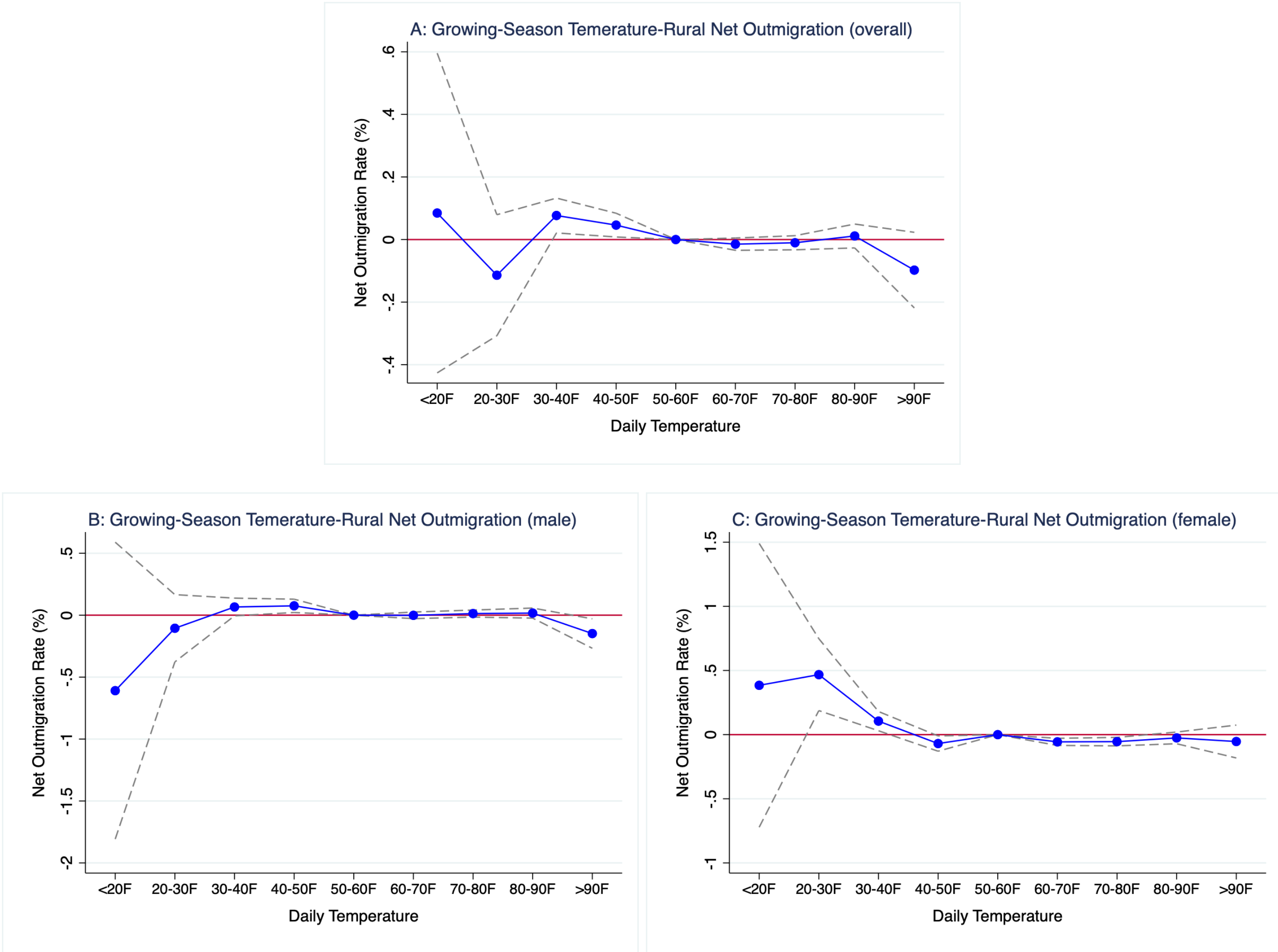
Notes: This figure depicts the estimated relationship of temperature and overall (panel A), male (panel B), and female (panel C) net outmigration. Point estimates are shown by the blue line with dots. The gray dashed line is the associated 95% confidence intervals. Each panel is a separately estimated regression using equation (2). Omitted group is the bin 50-60°F. Standard errors are clustered at county level.

Figure 4: Estimated Effects of Daily Temperature on Rural Male and Rural Female Net Outmigration



Notes: This figure depicts the estimated relationship of temperature and rural (panel A), rural female (panel B), and rural male (panel C) net outmigration. Point estimates are shown by the blue line with dots. The gray dashed line is the associated 95% confidence intervals. Each panel is a separately estimated regression using equation (2). Omitted group is the bin 50-60°F. Standard errors are clustered at county level.

Figure 5: Estimated Effects of Growing-Season Temperature on Rural Male and Rural Female Net Outmigration



Notes: This figure depicts the estimated relationship of growing-season temperature and rural (panel A), rural male (panel B), and rural male (panel C) net outmigration. Point estimates are shown by the blue line with dots. The gray dashed line is the associated 95% confidence intervals. Each panel is a separately estimated regression using equation (2). Omitted group is the bin 50-60°F. Standard errors are clustered at county level.

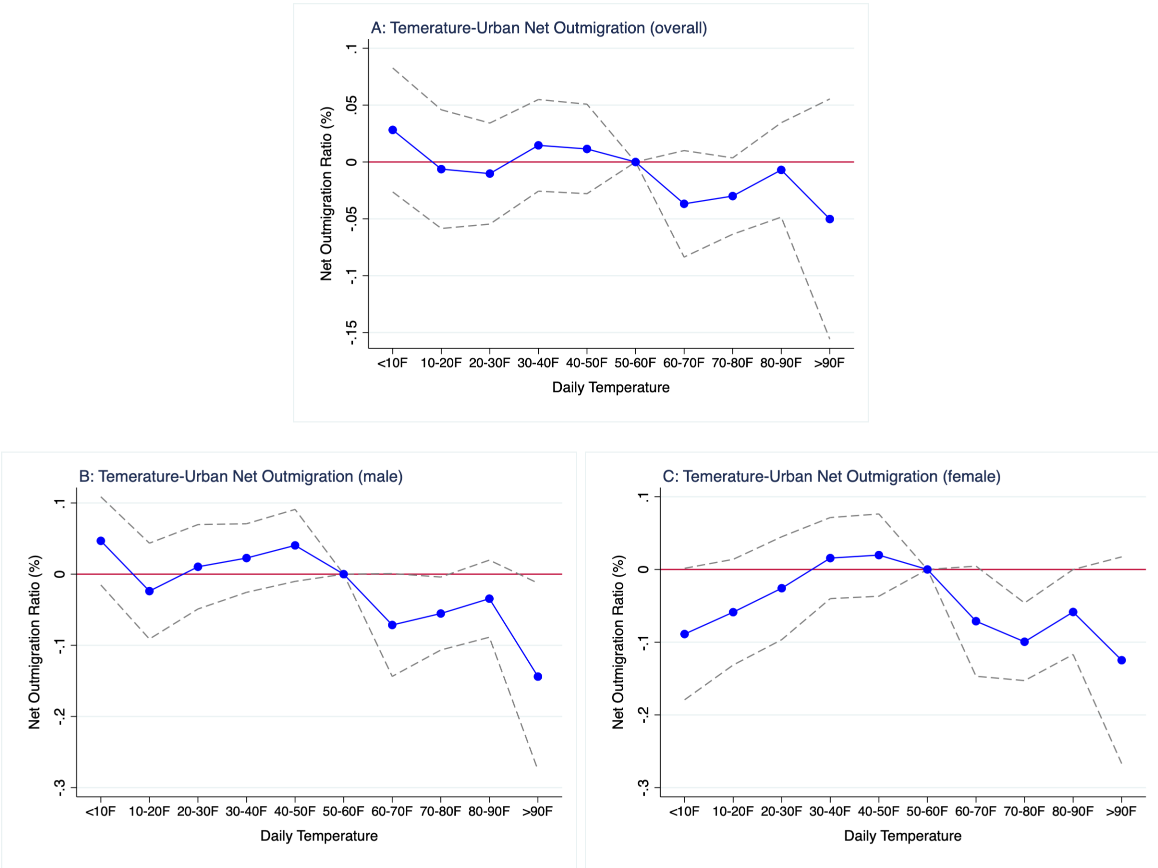
Table I: Summary Statistics by Period

	1995-2009	1995-1999	2000-2004	2005-2009
Migration				
Net Outmigration Rate (%)	-6.42	-6.47	-6.83	-5.95
	(12.32)	(11.30)	(15.64)	(9.10)
- Male	-22.22	-105.38	44.12	-5.55
	(64.08)	(19.15)	(15.56)	(10.90)
- Female	-25.53	-117.10	46.82	-6.47
	(70.21)	(21.22)	(15.51)	(10.99)
Temperature				
$<$10F (Days)	17.49	14.61	20.77	17.11
	(51.85)	(46.01)	(57.77)	(50.94)
10-20F (Days)	29.64	27.13	30.41	31.39
	(61.97)	(58.53)	(62.26)	(64.91)
80-90F (Days)	373.79	366.96	368.80	385.62
	(158.99)	(164.64)	(155.87)	(155.70)
$>$90F (Days)	180.41	164.31	179.74	197.19
	(162.06)	(123.37)	(141.77)	(207.26)
Observations	5538	1846	1846	1846

Notes: This table present the summary statistics (mean and standard deviation) of county-level analysis by periods. Net outmigration rate is defined as the percent of population leaving the county net of new arrivals. Only extreme temperature days are presented. Each variable's standard deviation is listed in the parenthesis.

A Appendix

Figure A.1: Estimated Effects of Daily Temperature on Urban Male and Urban Female Net Outmigration



Notes: This figure depicts the estimated relationship of temperature and urban (panel A), urban male (panel B), and urban female (panel C) net outmigration. Point estimates are shown by the blue line with dots. The gray dashed line is the associated 95% confidence intervals. Each panel is a separately estimated regression using equation (2) with county fixed effects and prefecture-by-year fixed effects. Omitted group is the bin 50-60°F. Standard errors are clustered at county level.