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Migrant Regularization as Climate Adaptation*

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Abstract

We show that granting migrants legal status enables climate adaptation by making extreme heat less dangerous. We study Spain's 2005 regularization program, which granted work permits to approximately 600,000 undocumented migrants. We examine its effect on heat-related hospitalizations among working-age individuals, primarily for heat strokes resulting from strenuous work in high temperatures. Our triple-difference design combines the timing of the reform, cross-provincial variation in pre-reform shares of undocumented migrants, and within-province variation in extreme heat. Following regularization, an additional day above 35°C became 3.3 percentage points less likely to result in a heat-related hospitalization in exposed provinces relative to unexposed provinces, a 9.4% decline relative to the pre-reform mean. The evidence points to improved outside options as the main mechanism: migrant workers reallocate away from agriculture, the most heat-exposed sector. These findings indicate that labor market institutions can facilitate climate adaptation by expanding workers' access to safer jobs.

Keywords: amnesty programs, climate adaptation, working conditions, extreme heat

JEL Classification: J46, J61, J81, Q54, Q56

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1 Introduction

Extreme heat can have fatal consequences. Since the 1990s, heat-related deaths have increased by 63%, reaching an estimated 546,000 deaths per year in 2012–2021. This largely reflects the higher incidence of days of extreme heat: in 2020–2024, the average person faced 19 days of health-threatening heat per year (Romanello et al., 2025). However, heat does not affect everyone equally. Vulnerability to extreme heat is shaped by physiological factors, such as age and health status, and by exposure factors, such as occupation and socio-economic conditions (Dillender, 2021; World Health Organization, 2024). Undocumented migrants are particularly at risk: they are over-represented in outdoor, physically demanding occupations, and their exclusion from formal labor markets limits their access to jobs offering higher wages and safer working conditions. Low bargaining power may limit their ability to reduce working hours, an important margin of response to extreme heat (Graff Zivin and Neidell, 2014). Granting undocumented migrants legal status can therefore be a margin of climate adaptation. While the literature has focused on technology (Barreca et al., 2016), income (Carleton et al., 2022) and access to health care (Mullins and White, 2020), there is little evidence on how labor market institutions and regulations affect adaptation.

In this paper, we show that granting migrants legal status enables climate adaptation by making extreme heat days less dangerous. We study Spain’s 2005 regularization program, which granted work permits to approximately 600,000 previously undocumented migrants. Combining administrative hospital records, high-resolution climate data, and registry-based measures of the undocumented population, we find that the amnesty causally reduced hospitalizations for heat-related illnesses—primarily heat strokes—among working-age individuals. In this population, heat strokes are overwhelmingly caused by strenuous physical activity under high temperatures rather than by pre-existing health conditions (Epstein and Yanovich, 2019). Heat-related hospitalizations on very hot days thus provide a rare, administratively recorded measure of exposure to hazardous working conditions, at the core of what the International Labour Organization classifies as labor exploitation (ILO et al., 2022), and are otherwise notoriously difficult to observe.

To identify the effect of legal status, we implement a triple-difference design that combines the timing of the amnesty; cross-provincial variation in exposure, measured by the pre-reform share of undocumented migrants in the population; and within-province variation in the incidence of extreme heat. We ask whether a 35°C day became less dangerous after the reform in provinces with more undocumented migrants. Because identification comes from changes in this sensitivity, any characteristic of high-exposure provinces that shifts the level of hospitalizations is controlled for.

We find that, after regularization, an additional day above 35°C became 3.3 percentage points less likely to result in any heat-related hospital discharge (HRD) in exposed provinces relative to unexposed ones. This corresponds to a 9.4% decline relative to the pre-amnesty probability of 35.1% in months with at least one such day. Importantly, the effect is not explained by the intensification of labor inspections that accompanied the program: when inspection intensity competes for the

same variation in a horse-race specification, the amnesty coefficient is essentially unchanged while the inspections interaction is small and statistically insignificant. The results are robust to a battery of checks, including dropping Barcelona and Madrid; using continuous exposure measures; leave-one-out exercises by year and province; placebo tests using hospitalizations unrelated to heat; and placebo tests using hospitalizations of children and elderly patients.

Why does legal status protect workers from extreme heat? We provide evidence that improved outside options matter. Legal status allows workers to move out of the jobs where heat exposure is most severe. Upon obtaining work permits, migrants reallocated away from agriculture (the sector with the highest reported heat exposure in Europe) toward other sectors, where reported heat exposure is much lower (Eurofound, 2025). We show that in more exposed provinces the agricultural share of migrant employment fell by 5.1 percentage points while the share in other sectors rose by 5.8 percentage points. Individual work histories from administrative records confirm that a formal agricultural contract was a stepping stone rather than a destination: two years after the amnesty, 65% of migrants regularized in agriculture had left the sector.

Our findings contribute to three strands of literature. First, we add to research on climate and health, which documents a robust relationship between extreme temperature, mortality, and morbidity, and shows how adaptation attenuates it through income growth, air conditioning, or health infrastructure (Barreca et al., 2016; Carleton et al., 2022; Ballester et al., 2023). We identify a distinct margin of adaptation: labor market institutions. An otherwise similar 35°C day became substantially less dangerous once the workers most exposed to it gained access to the formal labor market.

Second, we contribute to the literature on the labor market effects of regularization programs, which has focused on employment and earnings (Cobb-Clark et al., 1995; Kossoudji and Cobb-Clark, 2002; Kaushal, 2006; Amuedo-Dorantes et al., 2007, 2012; Devillanova et al., 2018; Bahar et al., 2021; Fasani et al., 2021). Most closely related, Elias et al. (2025) show that the 2005 Spanish amnesty improved migrants’ formal employment prospects without harming natives, and examine hospital discharges among their ancillary outcomes. We differ by tying hospitalizations to exogenous heat shocks, which isolates the workplace-safety margin that comparisons of hospitalization levels cannot detect.

Third, our findings speak to the literature on labor coercion and exploitation, which has examined their historical roots (Acemoglu and Wolitzky, 2011; Naidu and Yuchtman, 2013; Ashraf et al., 2024; Dippel et al., 2020) and their contemporary drivers, including labor market power (Naidu et al., 2016), migration flows (Seifert and Valente, 2018), criminal organizations (Dipoppa, 2024), and the political environment (Carillo et al., 2023). Migrant workers face a risk of exploitation three times higher than that of native workers (ILO et al., 2022), yet evidence on how legal status shapes their working conditions is scarce, partly because exploitation is, by its nature, hard to observe. We do not observe coercion or underpayment directly; rather, we measure one extreme, administratively recorded manifestation of hazardous work and show that it responds to legal status. This measurement approach is portable to other settings where exploitation is suspected but

unobserved.

2 Institutional Background

Spain offers a unique setting to study our research question. Undocumented migrants in Spain have a strong incentive to register in the *Padrón Municipal* (Municipal Registry of Population) because registration confers access to public health care and education under the same conditions as Spanish nationals and regular migrants.¹ This feature allows us to credibly measure the size of the undocumented migrant population by comparing the number of foreign residents recorded in the *Padrón* with the number of valid residency and work permits issued annually (see [Section 3](#)).

Spain has a large informal economy, which provides employment opportunities for undocumented migrants ([González-Enríquez, 2009](#)). Undocumented migrants are disproportionately employed in agriculture, construction and hospitality—sectors characterized by poor working conditions, including exposure to health risks, long working hours, job instability, low wages, and high levels of informality. Conditions in agriculture are notoriously poor: 37% of agricultural workers in the EU report being exposed to excessive heat, higher than any other sector and more than twice the average (15%).² In Spain, this is likely to be much higher.³ Some studies have documented high exposure to health risks and work-related accidents in agriculture ([Ekmekci and Yaman, 2024](#); [de Assis et al., 2021](#)).

The prevalence of undocumented migration varies substantially across Spain. Panel (a) of [Figure 1](#) shows the distribution across provinces of undocumented migrants in 2004, the year before the reform. They are more concentrated in eastern Spain and, as expected, in provinces where the agricultural sector is larger. The spatial distribution of undocumented migrants working in agriculture is similar to the distribution of undocumented migrants overall, as shown in [Appendix Figure A.1](#).

Between February and May 2005, the Spanish government implemented a large-scale regularization program that granted legal status to approximately 600,000 undocumented migrants. The program targeted individuals with prior residence in the country and ties to the Spanish labor market. To qualify, applicants had to be registered in the *Padrón* before August 2004 and obtain a valid job offer: a minimum six-month contract for general employment and a minimum three-month contract for agricultural work.⁴ The policy was accompanied by an increase in the number of labor inspections to ensure compliance ([Elias et al., 2025](#)).

The scale and timing of the amnesty were largely unanticipated. In 2002, the ruling center-right government led by the People’s Party (PP) had ended all extraordinary regularization programs.

¹This right was suspended in 2012 and reinstated in 2018. Hence, undocumented migrants have a strong incentive to register throughout the entire study period (2000–2011).

²Source: European Working Conditions Survey 2024. The question asks: “How often are you exposed at work to high temperatures which make you perspire even when not working?”.

³Unfortunately, a breakdown by sector and country is not available, but Spain’s average for all sectors is 28%, compared to 15% in the EU.

⁴Additional exceptions applied in sectors such as construction and domestic work.

As of early 2004, forecasts predicted their re-election, in which case they would have been unlikely to adopt more pro-migration policies. However, the terrorist attacks of 11 March 2004 and the government’s response in the aftermath led to an electoral upset for the incumbent party. As a result, and unexpectedly, the center-left Socialist Party (PSOE) won the following election and formed a new government. For additional details, see [Montalvo \(2011\)](#) and [Elias et al. \(2025\)](#).

Panel (b) of [Figure 1](#) shows one of the key outcomes of the reform. The red line shows the share of migrants in the Spanish Labor Force Survey (*Encuesta de Población Activa*, LFS), which includes both formal and informal workers. The blue line shows the evolution of the share of migrants in the Social Security records, thus capturing only formal employment. Immediately after the amnesty, the share of migrants in Social Security rose from around 6 to 9%, closing the gap with the migrant share in the LFS.⁵ At the same time, the estimated share of undocumented migrants (purple line) fell sharply.⁶ This shows that the policy was successful in moving undocumented migrants from informal to formal employment. The transition of migrant workers from informal to formal jobs was concentrated in provinces with a high share of undocumented migrants, while provinces with few migrants saw less notable changes (see panels (c) and (d)).

Because undocumented migrants already had access to public health care, the amnesty affected only their access to formal employment. Hence, the effect that we measure on hospital discharges is likely to materialize through changes in working conditions rather than changes in demand for health care. However, migrants may have become more inclined to seek medical help after obtaining legal status. We examine this issue in [Section 6](#) and show that it is unlikely to explain our results.

3 Data

Hospital Discharges. To measure health hazards, we use data from the *Encuesta de Morbilidad Hospitalaria* (Hospital Morbidity Survey, EMH), an annual survey conducted by Spain’s National Institute of Statistics (INE) since 1977. The EMH collects information on hospital discharges from public, private, and military hospitals nationwide, drawing from administrative records and hospital admission logs. The unit of observation is the single discharge, that is, the release of a patient after at least one night in the hospital. It includes the standardized diagnostic code (ICD-9-CM) of the principal diagnosis, length of stay, type of admission and discharge, as well as demographic information of the patient such as age, gender, and place of residence. The EMH employs a stratified two-stage sampling design, achieving near-universal coverage of hospital discharges (approximately 99.5%).

Our main outcome variable is derived by focusing on heat-related discharges (HRDs), defined as discharges coded under ICD-9 code 992, which includes, for example, heat stroke and sunstroke

⁵We access Social Security records through the *Muestra Continua de Vidas Laborales* (MCVL), which provides individual-level data on the employment histories of a representative sample of workers affiliated with the Spanish Social Security system. As such, it is representative of the formal labor force.

⁶Note that this is similar to the difference between the share of migrants in the LFS and the Social Security records.

(992.0) and various forms of heat exhaustion (992.3–992.5). We also restrict the data to working-age patients (aged 15–64), and define the variable y_{pym} as the count of HRDs occurring in province p and year-month ym . Our main outcome will be Y_{pym} , an indicator equal to one if there is at least one HRD in province p and year-month ym .

Municipal Registry. We use the Spanish Municipal Registry (*Padrón*) to measure the population in each municipality from 2000 to 2011. To measure population counts by nationality, we use the person-level microdata for the period 2003–2007. We then construct annual province-level aggregates of the native- and foreign-born population, further disaggregated by EU and non-EU citizenship. As explained above, undocumented migrants are allowed and strongly encouraged to register in the *Padrón*, making it a reliable source for measuring the *de facto* population regardless of legal status.

Reform Exposure. To estimate the size of the undocumented migrant population, we combine data from the *Padrón* with administrative records on valid residency permits, which include both work and student permits. For each province and year, we calculate the stock of undocumented migrants as the difference between the number of registered foreign residents and the number of valid permits. This measure is further disaggregated by EU and non-EU citizenship.

We define a province’s exposure to the amnesty program as a function of the share of the undocumented population over the total population. Specifically, our exposure variable is

$$ShUndoc_p = \frac{\text{Migrants}_p - \text{Residency Permits}_p}{\text{Population}_p} = \frac{\text{Undocumented}_p}{\text{Population}_p}$$

where all values refer to 2004, the year before the amnesty program.⁷ To simplify the interpretation of the coefficients, we classify provinces as either exposed or not exposed using a median split, thus defining the binary variable:

$$HiUndoc_p = \mathbb{1}\{p : ShUndoc_p \geq \text{Median}(ShUndoc)\}$$

The median split is also motivated by panels (c) and (d) in [Figure 1](#). The movement in the share of undocumented migrants is almost fully concentrated in provinces with an above-median share of undocumented migrants.

Reform Exposure in Agriculture. In the second part of the analysis, we refine our exposure measure to better capture the relative size of the undocumented migrant population employed in the agricultural sector. To this end, we use the LFS, a quarterly household survey that provides information on sectoral employment shares by nationality. The LFS asks whether respondents worked during the previous week, regardless of legal status, thereby capturing both formal and informal workers.

⁷To be exact, the 2004 exposure is *Padrón* at 1 January 2004 minus permits at 31 December 2003.

Using these data, we compute the share of migrants employed in agriculture at the province-year level as

$$ShAgri_p = \frac{\text{Migrants in Agriculture}_p}{\text{Migrant Employees}_p}$$

We then proxy for the relative size of the undocumented migrant population working in agriculture using the following measure:

$$ShAgriUndoc_p = \frac{\text{Undocumented}_p \times ShAgri_p}{\text{Population}_p}$$

where all variables refer to the year 2004. This proxy is valid under the assumption that the agricultural employment share among undocumented migrants is similar to that among documented migrants. As before, we use a median split to construct a binary indicator:

$$HiAgriUndoc_p = \mathbb{1}\{p : ShAgriUndoc_p \geq \text{Median}(ShAgriUndoc)\}$$

Climate Data. A key object of interest in our analysis is the sensitivity of HRDs with respect to the number of extreme heat days. We draw data on maximum temperature from the Spanish Temperature at Daily Scale (STEAD) dataset, which provides daily maximum and minimum temperature estimates on a 5km $\times$ 5km grid for peninsular Spain (1901–2014) and the Balearic and Canary Islands (1971–2014), based on data from over 5,500 meteorological stations (Serrano-Notivoli et al., 2019).⁸

To match our geographic and temporal units of analysis, we aggregate the data to the province-year-month level as follows. First, we assign each cell c to a municipality $muni$ based on its centroid. For each municipality, we compute the average daily maximum temperature across all cells it contains. We then aggregate to the province-day level using fixed municipal population weights from the year 2000, following Carleton et al. (2022). Formally, the daily maximum temperature in province p on day d is:

$$T_{pd} = \sum_{muni \in p} \frac{pop_{muni}}{pop_p} \sum_{c \in muni} \frac{T_{cd}}{N_{muni}^c}$$

where T_{cd} is the maximum temperature in cell c on day d , N_{muni}^c is the number of cells in municipality $muni$ and pop_{muni} , pop_p are the population in municipality $muni$ and province p in 2000, respectively. Finally, we compute the number of days on which the province-level temperature T_{pd} falls within one of eight predefined temperature intervals, each spanning 5°C, starting from 0°C, with an open-ended top bin for temperatures above 35°C. Our main climatic regressor is D_{pym}^{35+} , which denotes the number of days in year-month ym when the maximum temperature in province p falls into the top temperature bin (above 35°C). In our regression specification, we include indicators for all other temperature bins, using the 16–20°C bin as the omitted reference

⁸STEAD employs an exhaustive quality control process and a novel reconstruction methodology that leverages all available station data—rather than relying only on long historical series—to fill gaps and interpolate temperature values. Local generalized linear mixed models are used to predict temperatures at each grid point and day, incorporating geographic features such as latitude, longitude, altitude, and distance to the coast.

category.

Labor Inspections Data. To assess whether the amnesty’s effect operates through enforcement rather than legalization alone, we draw on administrative records published by the *Organismo Estatal Inspección de Trabajo y Seguridad Social* (OEITSS), the agency responsible for enforcing labor and immigration law in Spain. We use data for 2004 and 2005 that report, at the province-year level, the number of inspection actions, detected violations, fines imposed, and workers affected by violations, separately for the broader Employment and Immigration area and the Immigration sub-area. We match these records to the 47 provinces of peninsular Spain and construct our main inspection measure to be the (log) number of inspection actions in the Employment and Immigration area in province p and year t . We use the number of inspections in 2004, $\text{Insp}_{p,2004}$, and in 2005, $\text{Insp}_{p,2005}$, as two time-invariant proxies for enforcement intensity. They represent enforcement intensity at baseline and after the amnesty, respectively. These variables allow us to disentangle the role of enhanced inspections from that of legalization itself, as discussed in [Section 6](#).

Final Sample. Our main dataset is a balanced panel of the 47 provinces of peninsular Spain observed over 144 months, from January 2000 to December 2011. We truncate the sample in 2011, as undocumented migrants were excluded from access to public health care starting in 2012. We define the period from January 2000 to December 2004 as the pre-amnesty period, and January 2005 onward as the post-amnesty period. [Appendix Table A.1](#) presents summary statistics of the main variables.

4 Empirical Strategy

Our identification strategy leverages three distinct sources of variation. First, we exploit temporal variation by comparing outcomes before and after the implementation of the 2005 amnesty. Second, we use cross-provincial variation in exposure to the reform, proxied by the relative size of the undocumented migrant population, both overall and focusing on agricultural employment. Third, we exploit variation in temperature across provinces and over time, and examine whether the sensitivity of HRDs to excessive heat exhibits a structural break after the reform, particularly in provinces exposed to the amnesty. This motivates a triple-difference specification. We ask whether a 35°C day became less dangerous after 2005 in exposed provinces compared to unexposed ones.

Incorporating temperature and the incidence of excessive heat days as an additional source of variation allows us to address the main threats to identification that would arise in a simpler difference-in-differences framework comparing provinces with high versus low exposure to the reform over time. A key concern in such a setup is that provinces with larger undocumented populations may differ systematically from others along dimensions correlated with both the reform and health outcomes. By leveraging temperature shocks, we isolate differential impacts across provinces based on their exposure to heat stress, thereby strengthening the credibility of our identification strategy.

4.1 Estimating equation

We implement the following regression specification:

$$Y_{pym} = \beta D_{pym}^{35+} \times HiUndoc_p \times Post_{ym} + f(D_{pym}^{35+}, HiUndoc_p, Post_{ym}) + \mathbf{X}'_{pym}\gamma + \mathbf{W}'_{pym}\theta + \mathbf{Z}'_{pym}\lambda + \eta_{pm} + \alpha_{ym} + u_{pym} \quad (1)$$

where Y_{pym} is a binary indicator equal to one if any HRD is recorded in province p , year y and month m , D_{pym}^{35+} is the number of days on which the daily maximum temperature exceeded 35°C , $Post_{ym}$ is an indicator for the post-amnesty period (January 2005 onward) and $HiUndoc_p$ is an indicator equal to 1 for provinces with an above-median share of undocumented migrants. $f(\cdot)$ is a linear function of its arguments and their pairwise interactions. $\mathbf{X}_{pym}$ is a vector of climatic controls.⁹ $\mathbf{W}_{pym}$ is a vector of province-level labor market controls measured before the amnesty.¹⁰ $\mathbf{Z}_{pym}$ is a vector of province-specific linear and quadratic trends, fully interacted with both $Post_{ym}$ and $HiUndoc_p$. η_{pm} and α_{ym} are province-month and year-month fixed effects. Finally, u_{pym} captures any other residual determinant of the outcome variable of interest. We allow the errors to be correlated across observations belonging to the same province by clustering standard errors at that level.¹¹

The coefficient of interest is β , which captures whether the sensitivity of HRDs with respect to excessive heat exhibits a structural break following the offer of work permits to the undocumented population, specifically in provinces exposed to the amnesty relative to unexposed ones. Because the outcome variable is an indicator, the estimates should be interpreted as extensive-margin effects.

Sensitivity of HRDs to temperature by difference-in-differences cell. To show our results graphically, we estimate the sensitivity of HRDs to temperature by plotting the profile of coefficients associated with each temperature bin. We estimate these coefficients separately for each of the four cells defined by the difference-in-differences design. These cells are: exposed provinces before the amnesty, exposed provinces after the amnesty, unexposed provinces before the amnesty, and unexposed provinces after the amnesty. For each cell, we estimate the following specification:

$$Y_{pym} = \sum_{T=(0,5), T \neq (15,20)}^{35+} \beta_T D_{pym}^T + \mathbf{X}'_{pym}\gamma + \mathbf{W}'_{pym}\theta + \mathbf{Z}'_{pym}\lambda + \eta_{pm} + \alpha_{ym} + u_{pym} \quad (2)$$

where the outcome, controls and fixed effects are defined as in [equation \(1\)](#); D_{pym}^T are counts

⁹ Climatic controls include the count of days in temperature bins other than $35^\circ\text{C}+$ (see [Section 3](#)) and monthly precipitation, fully interacted with both indicators $Post_{ym}$ and $HiUndoc_p$.

¹⁰ Province-level controls include: log population (migrant and native) in 2003 and 2004; the number of unemployment benefit recipients; the log of the average (formal) wage; the average number of days worked per month; the employment shares in agriculture, hospitality, and in the public sector; the share of part-time contracts, all measured in 2004; a coastal indicator; and finally their interactions with both indicators $Post_{ym}$ and $HiUndoc_p$.

¹¹ In using this specification we follow the literature on climate and health ([Barreca et al., 2016](#)).

of days averaging a temperature within a 5°C temperature bin T ; we omit the $15^\circ - 20^\circ$ bin.

The profile of coefficients β_T describes the association between heat and HRDs. We expect the coefficients associated with low temperatures to be close to zero, and coefficients associated with high temperatures to potentially be positive. Our main interest lies, however, in comparing β_T coefficients across the four cells defined by the amnesty program and the corresponding exposure measure. If the amnesty program had an effect on the sensitivity to heat, we would expect (a) the coefficient β_{35+} to drop in exposed provinces, and (b) this drop to be larger in exposed provinces than in unexposed ones.

Dynamic specification. In order to test for the presence of pre-amnesty trends in HRD, and to learn the timing of the effects, we also estimate a dynamic triple-difference specification. We replace the $Post_t$ dummy variable with year indicators. We estimate the following dynamic specification:

$$Y_{pym} = \sum_{k=2000, k \neq 2004}^{2011} \beta_k D_{pym}^{35+} \times HiUndoc_p \times \mathbb{1}\{t = k\} + f(D_{pym}^{35+}, HiUndoc_p, Post_{ym}) + \eta_p + \alpha_{ym} + u_{pym} \quad (3)$$

where the outcome and regressors are defined as in [equation \(1\)](#); η_p and α_{ym} are province and year-month fixed effects, respectively. We omit province-level controls and province-specific trends to avoid fitting an excessive number of parameters.¹²

We then test whether the coefficients β_k for $k \in \{2000, \dots, 2003\}$ are jointly equal to zero, using an F-test with standard errors clustered at the province level. Given the small number of clusters, we also report wild cluster bootstrap p-values ([Cameron et al., 2008](#); [Roodman et al., 2019](#)).

5 Results

5.1 Main results

The results indicate that the amnesty program reduced the sensitivity of HRDs to extreme heat in exposed provinces. Our preferred specification suggests that, following the amnesty, one day with a maximum temperature above 35°C is 3.3 percentage points less likely to cause any HRD. This represents a 9.4% decline relative to the pre-amnesty mean of the outcome in months with at least one very hot day, equal to 0.351.

[Table 1](#) presents the estimates of the parameters in [equation \(1\)](#). We begin by presenting the estimated coefficients from a simplified model with only province fixed effects in column 1. Because this specification does not account for time-varying shocks (such as seasonal variation in temperature), we expect to detect an association of extreme heat with HRDs. Reassuringly, we find that very hot days significantly increase the likelihood of a heat-related discharge. The triple

¹²Interacting the full specification of [equation \(1\)](#) with twelve year indicators yields 3,016 non-absorbed parameters on 6,768 observations and 47 clusters.

interaction term, which captures the differential change in the association of heat and HRDs in high-exposure provinces after the reform, is negative and significant, consistent with our hypothesis.

In column 2, we add year-month fixed effects and pre-amnesty province-level controls. The triple interaction coefficient remains negative and significant, again consistent with our hypothesis. Unsurprisingly, the direct effect of extreme heat is muted. In column 3, we introduce province-month fixed effects as well as province-specific linear and quadratic trends. This is the full model of [equation \(1\)](#). In this more demanding specification, the triple interaction coefficient remains negative, similar in magnitude, though significant at the 10% level.

Our preferred specification, shown in column 4, restricts the sample to the warm season (May–September). Under this specification, the estimated effect becomes larger in magnitude and statistically significant at the 5% level. In column 5, we show the estimates of a logit model including the full set of climatic and labor market controls, as well as province and year-month fixed effects. The coefficient on the triple interaction is negative and significant at the 5% level.

The coefficient on the interacted $D^{35+} \times Post$ variable is never significant, indicating that there is no detectable effect in provinces with a low share of undocumented migrants. The same is true for the coefficient on $Post \times HiUndoc$, which suggests that a simple difference-in-differences design that does not exploit the variation in temperature would not be able to detect any effect on HRDs and therefore on working conditions.¹³

[Figure 2](#) provides a graphical representation of the results, estimated according to the model in [equation \(2\)](#). We estimate the sensitivity of HRDs to temperature separately for each of the four groups defined by the difference-in-differences design, and plot the coefficient associated with each temperature bin. Because the results are more precisely estimated, we classify provinces using the share of undocumented migrants in agriculture, but results are similar when using the share of undocumented migrants overall (as shown in [Appendix Figure A.2](#)).

The figure provides several insights that corroborate our interpretation of the regression results. First, the coefficients on temperature bins lower than 25°C are small and not statistically significant. Second, they become significant from the 26–30°C bin, and only in provinces with a high share of undocumented migrants in agriculture. Third, and most importantly, the figure clearly shows the decline in the sensitivity of HRDs to extreme heat in provinces exposed to the amnesty: the estimated sensitivity is 0.057 [0.021, 0.093] in the pre-amnesty period (2000–2004) and 0.007 [−0.017, 0.031] in the post-amnesty period (2005–2011). The difference between the two is −0.050 and significant at the 5% level ($p = 0.011$).¹⁴ By contrast, the sensitivity in unexposed provinces is not distinguishable from zero in either period, and does not change appreciably after the amnesty. This is consistent with the medical literature: in the absence of strenuous physical activity in the heat, heat stroke affects mainly the elderly and not the working-age population ([Epstein and Yanovich, 2019](#)).

¹³The coefficients in columns 2 to 5 are large and imprecisely estimated because of near-collinearity with the controls and fixed effects.

¹⁴This test comes from estimating both periods jointly with all regressors and fixed effects interacted with the post-amnesty indicator and standard errors clustered at the province level.

5.2 Pre-trends and placebo

Dynamic specification. For the validity of our approach, we need to rule out that the sensitivity of HRDs to extreme heat had been decreasing in highly exposed provinces before the amnesty program. For example, this would be a concern if agricultural employers had been adopting climate adaptation strategies already before the amnesty program. We evaluate this concern by estimating the dynamic triple-difference specification in [equation \(3\)](#). [Figure 3](#) plots the estimated coefficients. We can confidently rule out the presence of differential trends in climate adaptation before the amnesty program. The coefficients associated with pre-amnesty years are small and not statistically distinguishable from zero, and we cannot reject that they are jointly zero ($p = 0.460$; wild cluster bootstrap $p = 0.775$). On the other hand, we find that after the amnesty, all coefficients are negative. Overall, the pooled post coefficient that compares all post-amnesty periods to all pre-amnesty periods is -0.047 and highly significant ($p < 0.01$). Individually, the coefficient for 2005 is negative and significant at the 5% level, and the coefficient for 2008 is negative and significant at the 10% level. Hence, the reduction in the sensitivity of HRDs to heat occurred after the amnesty.

Non-heat discharges. We run two placebo checks that validate our approach. First, we replace the outcome of the model in [equation \(1\)](#) with discharges that should not be affected by heat shocks and by the amnesty program. We explore effects at both the extensive and intensive margin. In panel A of [Appendix Table A.2](#) we show effects at the extensive margin by regressing an indicator equal to one if the province had any discharge in the month. This is analogous to our main outcome. Since most discharge types always have at least one discharge per month, the extensive-margin outcome has variation only for HRDs (where the coefficient is negative and significant) and for intoxications, where the coefficient is small and insignificant. Panel B shows the results of regressions of the asinh counts of discharges. The estimates for HRDs and intoxications are relatively large but imprecise. The coefficients associated with all other discharges, including total discharges, are small and insignificant.

Children and elderly. Our second placebo check replicates the main specification using HRDs for patients aged 0–14 (children) and 65 or more (elderly). Their sensitivity to extreme heat should not change differentially after the reform, since the amnesty program grants work permits to working-age adults. [Appendix Table A.3](#) shows that the coefficients are small and insignificant for these populations.

5.3 Robustness

In [Appendix Table A.4](#), we test the robustness of our results to using continuous exposure measures rather than binary ones. Columns 1 and 2 reproduce the main results using the binary measures constructed from the share of undocumented migrants and the share of undocumented migrants in agriculture, respectively. In columns 3 and 4, we replace the two binary measures of exposure with continuous ones. The associated coefficients are negative and significant. Moving from the

25th to the 75th percentile of exposure reduces the sensitivity of HRDs to extreme heat days by 3.0 and 3.1 percentage points, respectively, which represent declines of 8.6% and 8.8% relative to the pre-amnesty mean.

Finally, we perform an additional battery of robustness checks. We exclude Madrid and Barcelona, the two major urban areas in Spain, which host a large migrant population but have relatively small agricultural sectors (see [Appendix Table A.5](#)). We exclude the rollout period of the amnesty program (see [Appendix Table A.6](#)), and we classify provinces by the non-EU migrant population (see [Appendix Table A.7](#)). Our results are robust to all of these checks.

6 Mechanisms

6.1 Sectoral reallocation

We document a large and robust decline in heat-related hospitalizations following days with extreme heat, driven by provinces with a large pre-amnesty population of undocumented migrants. We hypothesize that this reduction is driven by improved working conditions. As migrant workers gain access to the amenities associated with formal contracts, their bargaining power increases due to a larger set of outside options. While improvements within a sector are difficult to measure, this enhanced bargaining power should also be reflected in a greater ability for migrants to switch to sectors with better conditions. In particular, we argue that moving out of agriculture plays a key role. Before the reform, agriculture disproportionately employed migrant workers: in 2004, migrants were 26.5% of agricultural employees in the LFS, compared with 10.0% across all sectors. Additionally, informality was more prevalent: non-EU migrants were 25.0% of agricultural employees in the LFS (which counts formal and informal jobs) but only 13.1% of agricultural workers registered with Social Security.¹⁵ This suggests that undocumented migrants were disproportionately employed there. Agriculture is the sector with the highest reported heat exposure in Europe, higher than construction and any other sector ([Eurofound, 2025](#)).¹⁶

Consistent with this hypothesis, we find that the amnesty allowed migrants to transition from agriculture, a sector known for poor conditions, toward other sectors. [Figure 4](#) presents the primary evidence for this mechanism. Panel (a) displays the results from a dynamic difference-in-differences specification. We compare provinces with a high pre-amnesty share of undocumented migrants in agriculture to those with a low share, before and after the program, controlling for province-by-quarter, year-by-quarter fixed effects, and province-level controls interacted with the post-amnesty indicator.¹⁷ The reform led to a 5.1-percentage-point decrease in the agricultural share of migrant employment, and no changes for natives. Panel (b) tracks the careers of migrants that first appeared in Social Security records from February to August 2005 in the agriculture sector. We take these

¹⁵This gap is smaller in other sectors. The migrant share across all sectors is 8.9% in the LFS and 6.3% in Social Security records.

¹⁶37% of agricultural workers in the EU report being exposed to excessive heat, higher than any other sector and more than twice the average (15%). In Spain, this is likely to be much higher.

¹⁷For this exercise, our panel has a quarterly frequency due to the availability of the LFS.

individuals to be the migrants regularized in agriculture. Our finding is that they transition out of agriculture very quickly: two years after entering, only about 35% are still working in agriculture.

Overall, migrant workers mostly relocate to employment in other sectors, as shown in [Appendix Figure A.3](#) (see [Appendix Table A.8](#) for numerical details). The share of migrants employed in sectors other than agriculture and construction is positive (0.058) and significant. Although no single sector shows a positive and highly significant increase in the share of migrants employed, the coefficient for “Other services” is positive (0.064) and significant at the 10% level. This category includes domestic services, but we are unable to dissect it further due to the coarse nature of the classification.

6.2 Other channels: enforcement and health-seeking behavior

Labor inspections. First, we run two separate regressions where we substitute the measure of amnesty exposure with two variables that capture the intensity of inspections concerning foreign workers: the number of labor inspections by province in 2004 and the number of labor inspections by province in 2005. For comparability with the measure of exposure to the amnesty, we discretize each variable to an indicator equal to one if the province is above the median.¹⁸ The first variable captures baseline enforcement intensity, while the second captures enforcement intensity following the amnesty. If labor inspections explain the reduction of HRDs following the reform, the coefficients in these specifications should be negative and significant. Columns 2 and 3 in [Appendix Table A.9](#) show that the coefficients are small and not statistically significant. Second, in columns 4 and 5, we present results from a horse-race regression that includes both the main triple interaction and the triple interaction with inspections. If labor inspections, and not regularization, explain the effects, the inclusion of these regressors should attenuate the coefficient associated with reform exposure. Results show that the main triple interaction coefficient is essentially unchanged, while the triple interactions with inspections are small and statistically insignificant. Hence, it does not appear that the increase in labor inspections following the reform can, alone or in conjunction with reform exposure, explain the reduction in sensitivity of HRDs to extreme heat.

Increase in health-seeking behavior. A potential concern with our identification strategy is that, following regularization, undocumented migrants may have become more willing to seek medical attention when affected by extreme heat. If this were the case, we would expect to observe a *higher*, not lower, sensitivity of HRDs with respect to extreme heat in the post-reform period, particularly in provinces more exposed to the amnesty. This implies that our main finding of a lower sensitivity likely reflects a lower bound on the true protective effect of the reform.¹⁹ Thanks

¹⁸Results do not change when including inspections as continuous variables, or both reform exposure and inspections as continuous variables.

¹⁹A related concern implies a bias in the opposite direction. If undocumented migrants become more willing to seek medical attention, they may become healthier overall and less prone to heat strokes. However, in the adult non-elderly population, heat strokes are overwhelmingly caused by strenuous physical activity in high temperatures. They are not related to pre-existing health conditions ([Epstein and Yanovich, 2019](#)). Hence, access to better health care is unlikely to cause fewer HRDs.

to the data on the near-universe of hospitalizations, we can evaluate whether this bias exists. If undocumented migrants become more willing to seek medical attention after the amnesty program, we would expect total hospital admissions to increase differentially in more exposed provinces. [Appendix Table A.10](#) shows the coefficients from a difference-in-differences design comparing high vs. low exposure provinces, before and after the amnesty. The coefficient associated with the total number of discharges (excluding heat-related) is not significant.²⁰

7 Conclusions

This paper shows that granting legal status to undocumented migrants enables climate adaptation by making extreme heat days less dangerous. We study Spain’s 2005 regularization program, which granted work permits to approximately 600,000 undocumented migrants. Combining administrative hospital records, high-resolution climate data, and registry-based measures of the undocumented population, we implement a triple-difference design that exploits the timing of the amnesty, cross-provincial variation in exposure to it, and within-province variation in extreme heat.

We find that the sensitivity of heat-related hospital discharges (HRDs) among working-age individuals to very hot days declined after the amnesty in provinces with a larger pre-reform share of undocumented migrants. An additional day above 35°C became 3.3 percentage points less likely to result in any HRD in exposed provinces relative to unexposed ones, a 9.4% decline relative to the pre-amnesty mean. The decline starts in 2005, with no differential trends in the preceding years. We find no comparable change for hospitalizations unrelated to heat, nor for HRDs among children and the elderly, who were not eligible for work permits. The effect is of similar size with continuous exposure measures, when excluding Madrid and Barcelona, and excluding the rollout months of the program. It is not explained by the labor inspections that accompanied the program, nor by changes in migrants’ use of health care: total hospital discharges did not rise differentially in more exposed provinces.

Our evidence on mechanisms is consistent with legal status improving migrants’ outside options. After the amnesty, migrants in more exposed provinces moved out of agriculture, the sector with the highest reported heat exposure in Europe, and into other sectors. Individual work histories show that most migrants regularized with an agricultural contract left the sector within two years. Because our hospital data are aggregated at the province level, we cannot link these moves to individual hospitalizations, nor separate them from improvements in working conditions within jobs.

Our results identify labor market institutions as a margin of climate adaptation. The literature has emphasized income growth and the diffusion of air conditioning, which reduce the health burden of heat over decades. We show that a policy implemented over a few months changed how dangerous a hot day was for the workers most exposed to it. More broadly, heat-related hospitalizations on very hot days provide an administratively recorded measure of hazardous working conditions that

²⁰The coefficient associated with intoxications (Intox.) is negative and significant, while the coefficient associated with injuries (Inj.) is positive and marginally significant.

can be used in other settings where labor exploitation is suspected but hard to observe. As extreme heat becomes more frequent, the health of outdoor workers will depend not only on how hot it gets, but also on the institutions that determine who bears the heat, and on what terms.

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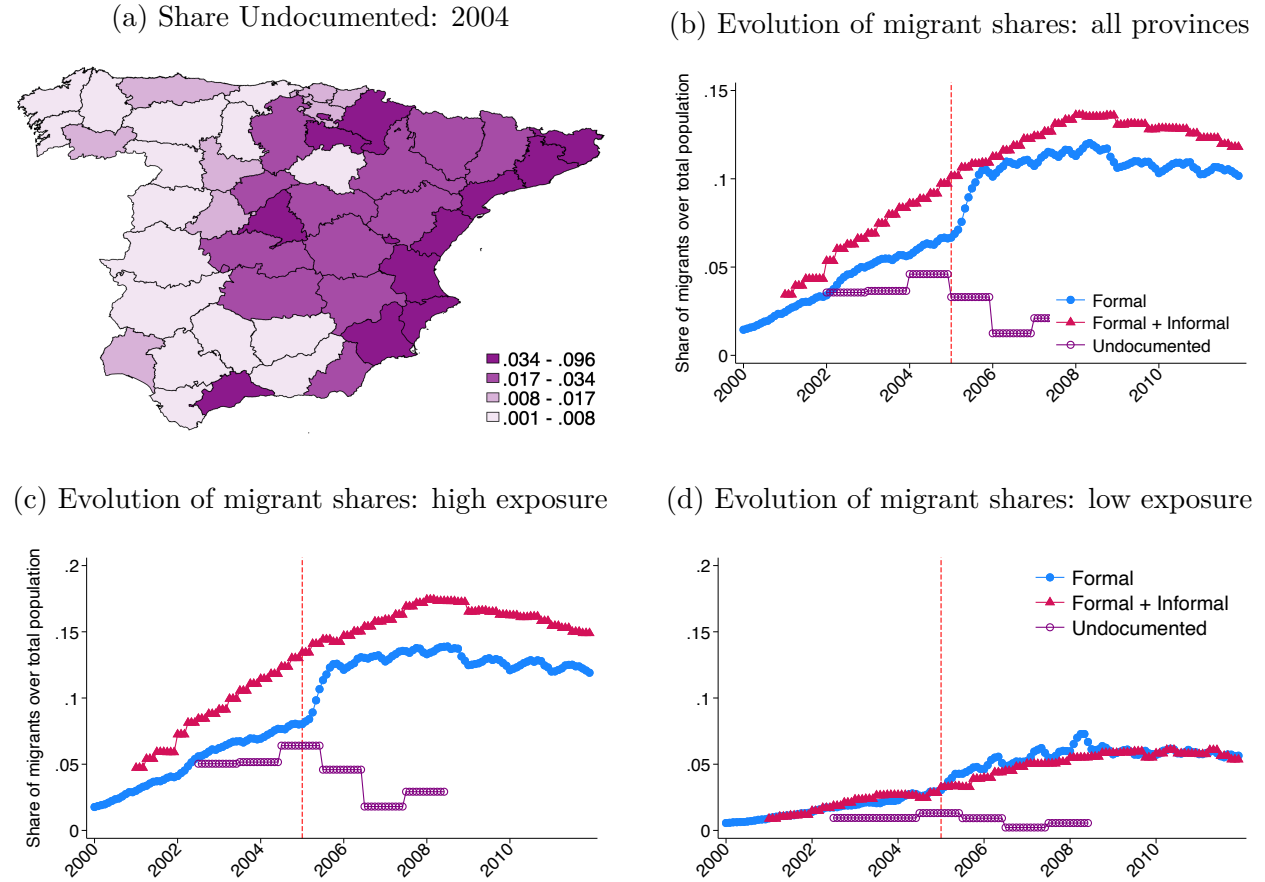
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Exhibits

Figure 1: Amnesty program descriptives



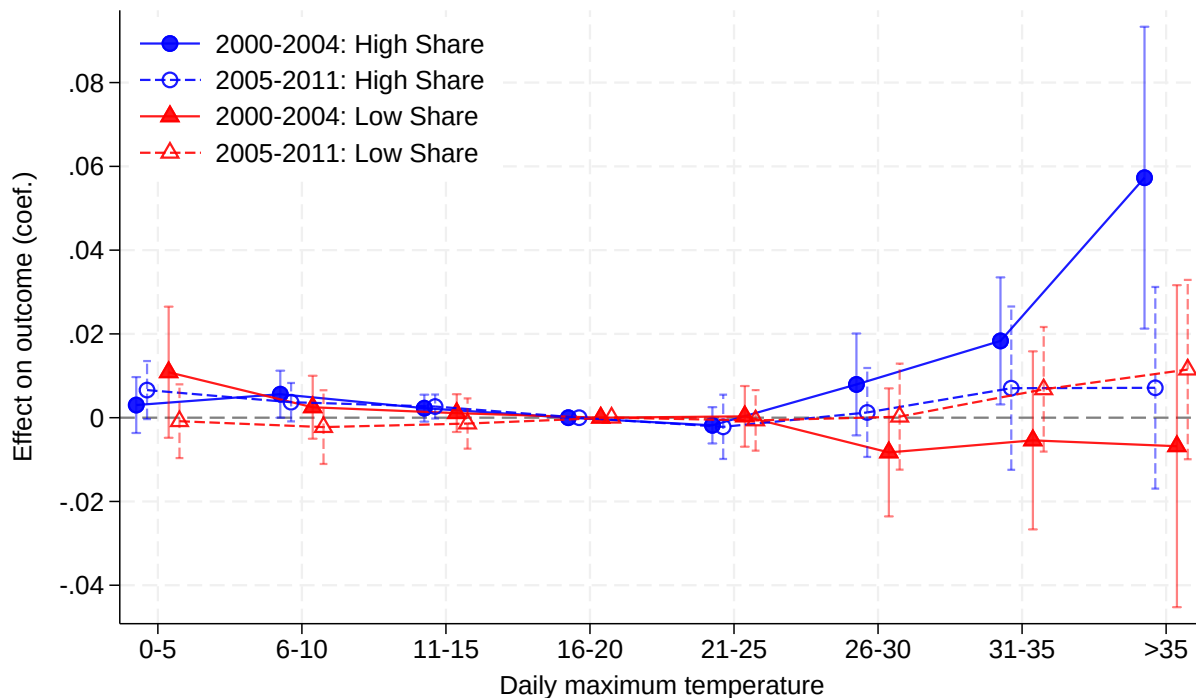
Note: Panel (a) presents the distribution of the share of undocumented migrants across Spanish provinces in 2004, the year before the amnesty program. The share of undocumented migrants is calculated by dividing the number of undocumented migrants by the number of inhabitants. For details see Section 3. Panel (b) plots the evolution of the share of migrants over total number of workers in the Labor Force Survey (red line) and in the Social Security records (blue line). The purple line presents the share of undocumented migrants over total population. Panels (c) and (d) show the same series for provinces with a high and a low share of undocumented migrants, respectively (see Section 3). Back to Section 2.

Table 1: Main estimates

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) Logit
$D_{pym}^{>35}$	0.020*** (0.006)	0.002 (0.007)	0.009 (0.011)	0.012 (0.015)	0.081 (0.057)
$D_{pym}^{>35} \times \text{Post}$	0.005 (0.006)	0.010 (0.007)	0.010 (0.008)	-0.001 (0.014)	0.051 (0.075)
$\text{Post} \times \text{HiUndoc}$	0.005 (0.038)	-3.961 (2.395)	24.460 (29.966)	-7.291 (60.226)	-33.053 (38.027)
$D_{pym}^{>35} \times \text{Post} \times \text{HiUndoc}$	-0.022** (0.011)	-0.024** (0.011)	-0.022* (0.012)	-0.033** (0.016)	-0.179** (0.079)
Year $\times$ Month FE		✓	✓	✓	✓
Prov $\times$ Month FE			✓	✓	
Full Controls		✓	✓	✓	✓
Linear + Quadratic trends			✓	✓	
May-Sep only				✓	
R2	0.256	0.301	0.403	0.389	
Pseudo R2					0.333
Obs.	6768	6768	6768	2820	5106

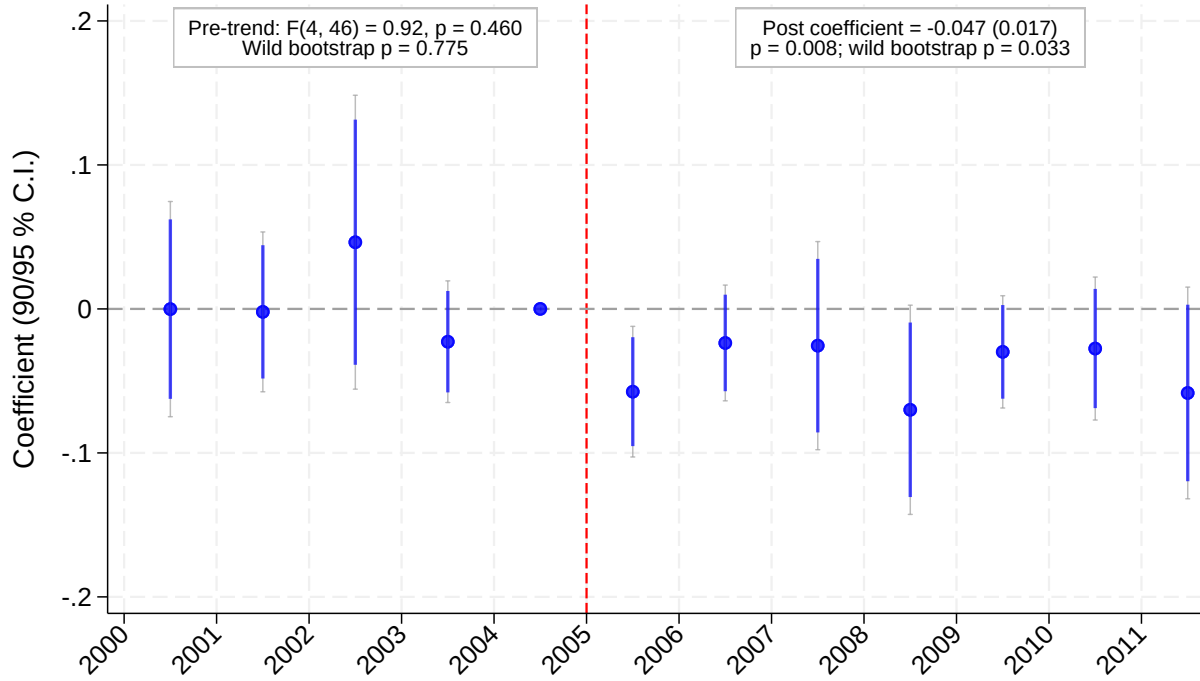
Note: This table presents the estimates of the parameters in [equation \(1\)](#). Column 1 presents the estimated coefficients from a simplified model with only province fixed effects. Column 2 adds year-month fixed effects and pre-amnesty province-level controls. Column 3 adds province-month fixed effects as well as province-specific linear and quadratic trends. Column 4 restricts the sample to the warm season (May–September) and, finally, column 5 presents the coefficient from a logit model including the full set of climatic and labor market controls, as well as province and year-month fixed effects. Controls include population (total and migrant) in 2003 and 2004, unemployment rate, employment in part-time, permanent, public, agricultural and hospitality jobs, average wage, days worked in 2004 and a coastal dummy. The outcome is an indicator for any heat-related discharge of working-age individuals. Standard errors are clustered at the province level. Back to [Section 5](#).

Figure 2: Estimated relationship between maximum temperature and heat-related hospital discharges of working-age population



Note: This figure presents the relationship between maximum temperature and HRD following [equation \(2\)](#) when we classify provinces using the share of undocumented migrants in agriculture. Each specification controls for province-month and year-month FE, province-specific linear and quadratic trends and monthly precipitation. The blue solid dots show coefficients estimated using data for the pre-amnesty period (2000–2004) and provinces with an above-median share of undocumented migrants in agriculture over total population. The blue hollow dots show coefficients estimated using data for the post-amnesty period (2005–2011) and provinces with an above-median share of undocumented migrants in agriculture over total population. The red solid triangles show coefficients estimated using data for the pre-amnesty period (2000–2004) and provinces with a below-median share of undocumented migrants in agriculture over total population. The red hollow triangles show coefficients estimated using data for the post-amnesty period (2005–2011) and provinces with a below-median share of undocumented migrants in agriculture over total population. Capped spikes show 95% confidence intervals. Standard errors are clustered at the province level. Back to [Section 5](#).

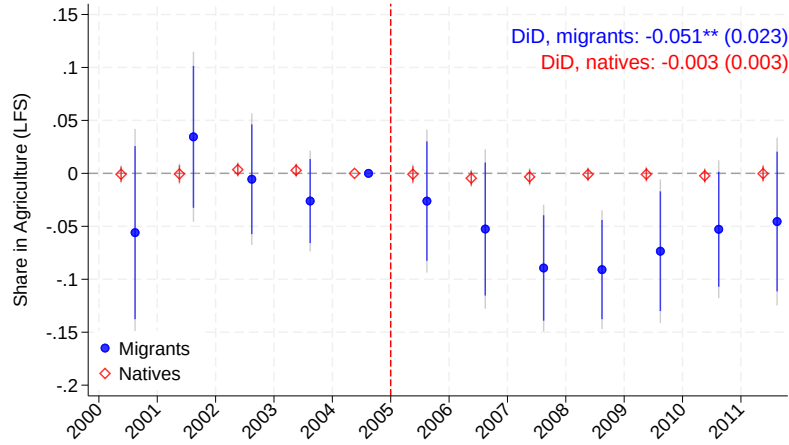
Figure 3: Dynamic triple-difference specification



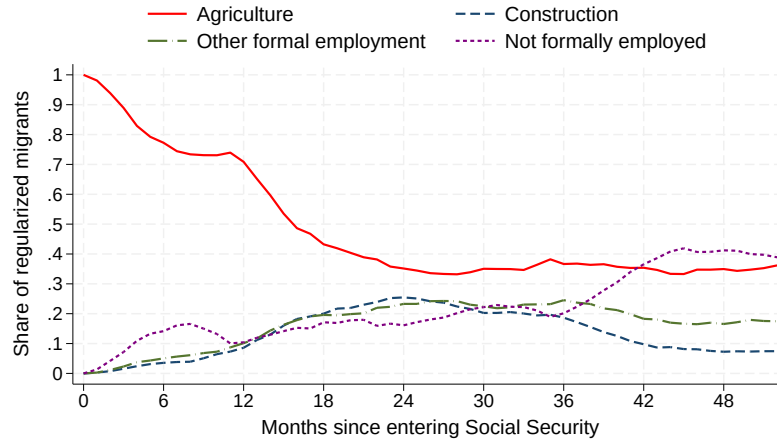
Note: The figure plots the coefficients β_k from a dynamic version of the triple-difference specification, in which the interaction between the number of days above 35°C in the month and an indicator for provinces with an above-median 2004 share of undocumented migrants in agriculture over total population is estimated separately for each year, with 2004 as the omitted year. The outcome is an indicator for at least one heat-related hospital discharge among working-age individuals (15–64) in the province-month. The specification includes monthly precipitation and the number of days in each daily maximum temperature bin ($15\text{--}20^\circ\text{C}$ omitted) fully interacted with year dummies and the exposure indicator, as well as province and year-month fixed effects. Standard errors are clustered at the province level. Thin grey spikes show 95% and thick blue spikes 90% confidence intervals. The dashed vertical line marks the 2005 regularization. The left box reports the joint F -test that the 2000–2003 coefficients are zero; the right box reports the average 2005–2011 coefficient minus the average 2000–2003 coefficient, with its standard error. Wild cluster bootstrap p -values use 9,999 replications with Rademacher weights, the null imposed, and clustering by province.

Figure 4: Mechanisms

(a) Dynamic DiD on the agricultural share



(b) Regularized migrants in agriculture

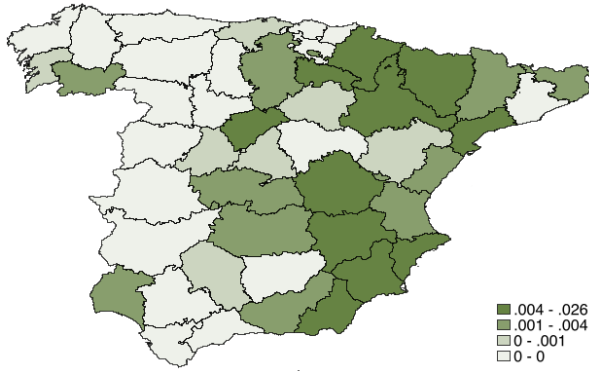


Note: Panel (a) shows estimated coefficients for a dynamic difference-in-differences regression of the agricultural share of employment on year dummies interacted with an indicator for provinces with an above-median 2004 share of undocumented migrants in agriculture over total population, with 2004 as the omitted year. Shares are computed from the quarterly Spanish Labor Force Survey, separately for migrants (blue solid dots) and natives (red hollow diamonds). Standard errors are clustered at the province level. Thin grey spikes show 95% and thick blue spikes 90% confidence intervals. The dashed vertical line marks the 2005 regularization. The coefficients printed in each panel are from the corresponding static difference-in-differences specification, which replaces the year interactions with a single post-2005 interaction, with standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Panel (b) follows the migrants who first entered Social Security records during the amnesty window in agriculture and the data come from the *Muestra Continua de Vidas Laborales* (MCVL) of the Spanish Social Security administration. Each line shows the share of the cohort in one of four labor-market states (agriculture; construction; other formal employment; or not formally employed) by month since entering Social Security. Each person-month is assigned to the state in which the individual worked the most days that month.

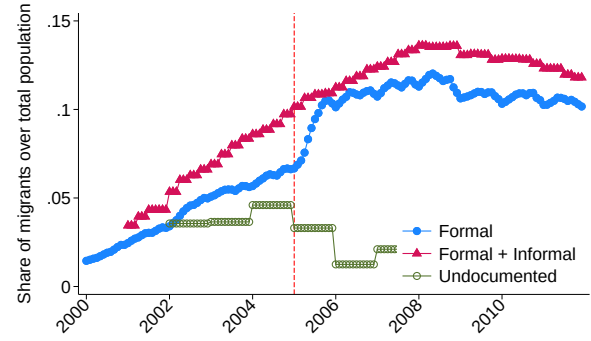
A Appendix Figures and Tables

Figure A.1: Amnesty program descriptives by share of undocumented migrants in agriculture

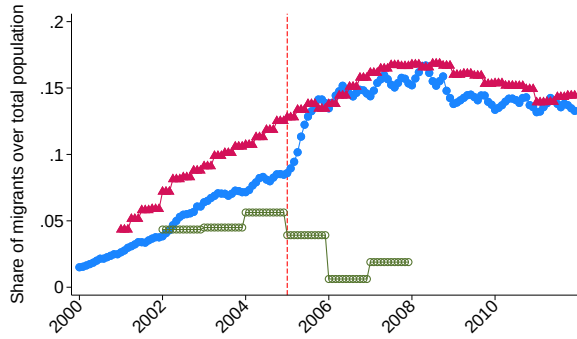
(a) Share undocumented in agriculture: 2004



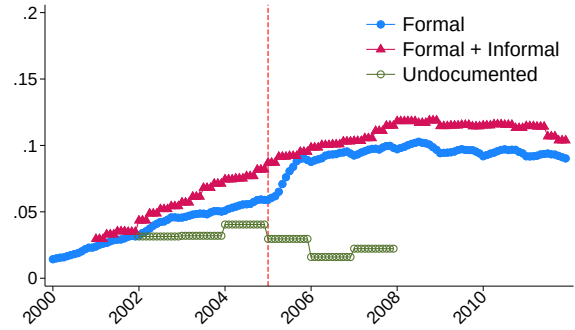
(b) Evolution of migrant shares: all provinces



(c) Evolution of migrant shares: high share of undocumented in agriculture

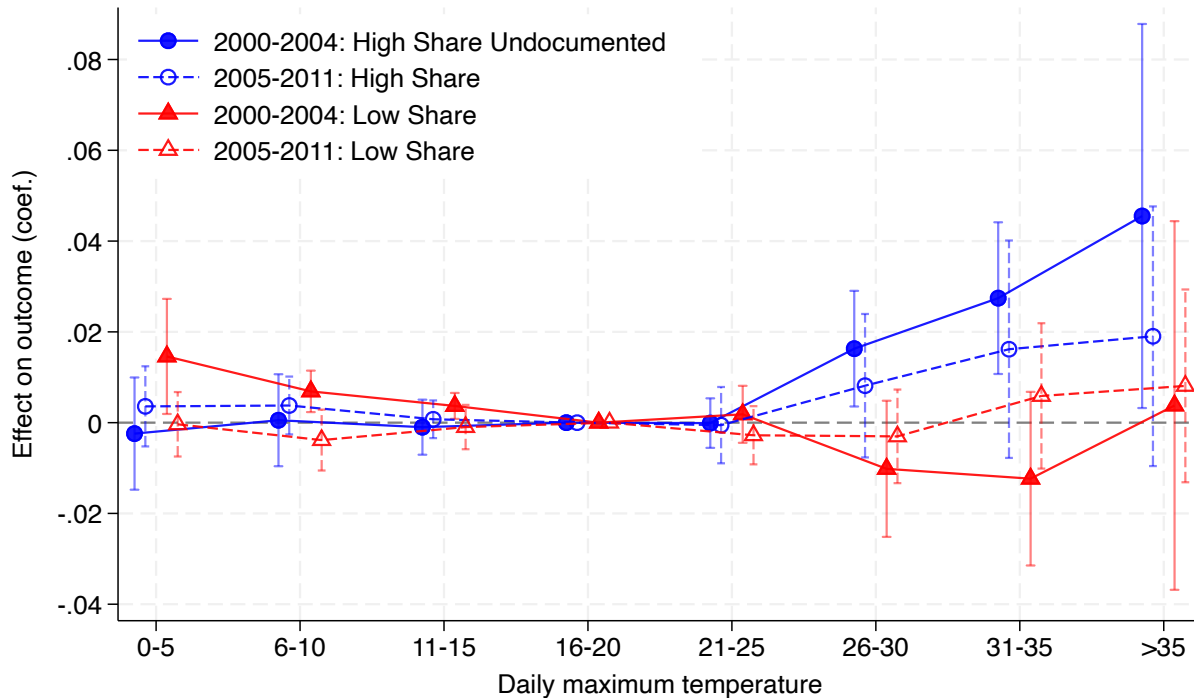


(d) Evolution of migrant shares: low share of undocumented in agriculture



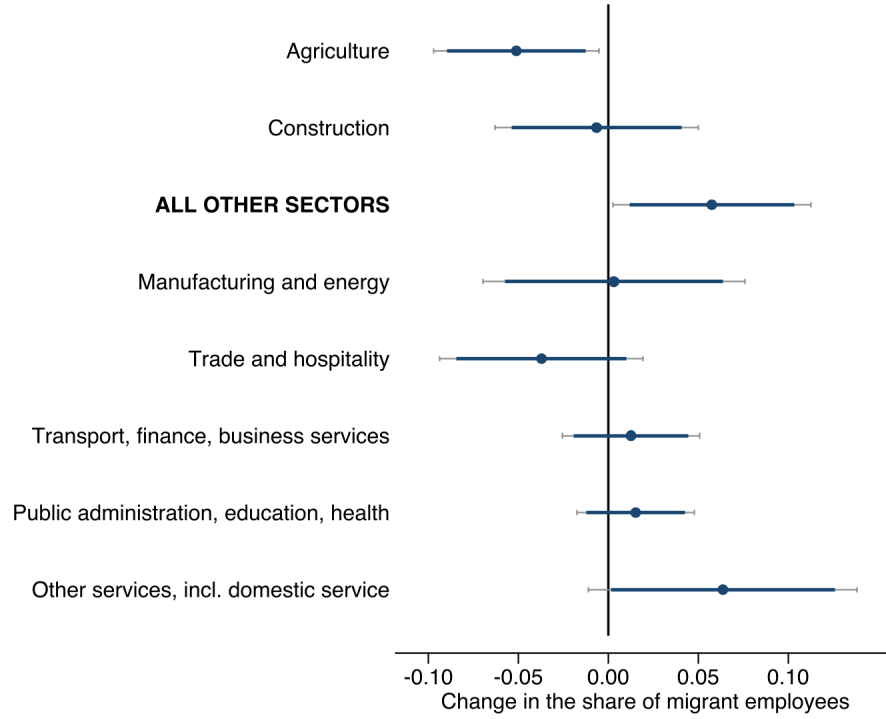
Note: Panel (a) presents the distribution of the 2004 share of undocumented migrants in agriculture over population, by quartile. Panels (b)–(d) plot the share of migrants over total workers in the Labor Force Survey (Formal + Informal) and in Social Security records (Formal), and the share of undocumented migrants over working-age population (Undocumented), for all provinces and for provinces above and below the median of that share. The vertical line marks January 2005. Back to Section 2.

Figure A.2: Estimated relationship between maximum temperature and heat-related discharges, using undocumented share



Note: This figure presents the relationship between maximum temperature and HRD following [equation \(2\)](#) when we classify provinces using the share of undocumented migrants. Each specification controls for province-month and year-month FE, province-specific linear and quadratic trends and monthly precipitation. The blue solid dots show coefficients estimated using data for the pre-amnesty period (2000–2004) and provinces with an above-median share of undocumented migrants over total population. The blue hollow dots show coefficients estimated using data for the post-amnesty period (2005–2011) and provinces with an above-median share of undocumented migrants over total population. The red solid triangles show coefficients estimated using data for the pre-amnesty period (2000–2004) and provinces with a below-median share of undocumented migrants over total population. The red hollow triangles show coefficients estimated using data for the post-amnesty period (2005–2011) and provinces with a below-median share of undocumented migrants over total population. Capped spikes show 95% confidence intervals. Standard errors are clustered at the province level. [Back to Section 5.](#)

Figure A.3: Difference-in-differences estimates on the sectoral shares of migrant employees



Note: This figure presents the coefficients from separate regressions of the share of migrant employees in each sector on $Post_t \times HiAgriUndoc_p$, with province-quarter and year-quarter fixed effects and pre-amnesty (2004) province-level controls interacted with $Post_t$, using the quarterly Spanish Labor Force Survey. The five rows below “All other sectors” are its components and add up to it. Thick bars show 90% and thin capped whiskers 95% confidence intervals. Standard errors are clustered at the province level. Trade includes hospitality, and other services include domestic service. Corresponding numerical details are in [Appendix Table A.8](#). Back to Section 6.

Table A.1: Summary statistics of the main variables

	<i>Descriptive statistics</i>					
	Observations	Mean	Median	SD	Min	Max
<i>A. Heat-related hospital discharges (province-month)</i>						
Any HRD, ages 15–64	6,768	0.116	0.000	0.321	0.000	1.000
Number of HRDs, ages 15–64	6,768	0.196	0.000	0.726	0.000	12.803
Any HRD, ages 0–14	6,768	0.031	0.000	0.172	0.000	1.000
Any HRD, ages 65+	6,768	0.083	0.000	0.276	0.000	1.000
<i>B. Weather (province-month)</i>						
Days above 35°C	6,768	0.513	0.000	2.350	0.000	24.000
Precipitation	6,768	18.038	12.890	18.723	0.000	203.561
<i>C. Exposure to the amnesty (province)</i>						
Undocumented share	47	0.022	0.017	0.019	0.001	0.096
High undocumented share	47	0.511	1.000	0.505	0.000	1.000
Agri. undocumented share	47	0.003	0.001	0.005	0.000	0.026
High agri. undoc. share	47	0.489	0.000	0.505	0.000	1.000
<i>D. Province characteristics in 2004 (province)</i>						
Population (million)	47	0.855	0.555	1.092	0.092	5.805
Immigrant share	47	0.051	0.037	0.036	0.013	0.157
Non-EU share	47	0.042	0.033	0.028	0.010	0.104
Share of workers in agriculture	47	0.046	0.027	0.049	0.003	0.239
Share of workers in hospitality	47	0.063	0.060	0.017	0.032	0.113
Share of part-time workers	47	0.145	0.144	0.025	0.086	0.194
Share of temporary contracts	47	0.380	0.344	0.108	0.196	0.687
Share of public-sector workers	47	0.089	0.084	0.073	0.006	0.359
Days worked per month	47	27.732	27.959	0.575	25.835	28.405
Daily wage (log)	47	3.692	3.672	0.160	3.436	4.278
Share on unemployment benefits	47	0.063	0.062	0.012	0.037	0.094
Coastal province	47	0.404	0.000	0.496	0.000	1.000
Labor inspections, foreign workers	47	662	184	1,283	37	7,627
<i>E. Sectoral shares of employees (province-quarter, LFS)</i>						
Migrants in agriculture	2,211	0.103	0.055	0.143	0.000	1.000
Migrants in construction	2,211	0.174	0.164	0.132	0.000	1.000
Natives in agriculture	2,256	0.036	0.025	0.035	0.000	0.337
Natives in construction	2,256	0.110	0.108	0.036	0.031	0.233

Note: This table presents summary statistics on the main variables. Panels A and B use the balanced monthly panel of the 47 provinces of peninsular Spain, observed from January 2000 to December 2011 (144 months). Panels C and D report one observation per province. HRD: heat-related hospital discharge. Exposure measures are defined in [Section 3](#). Panel D reports the pre-amnesty province-level controls, computed from Social Security records for 2004 (workers registered with Social Security), except population and migrant shares; daily wages are corrected for part-time work and inflation; labor inspections are the number of inspections concerning foreign workers in 2004. Panel E uses the quarterly Spanish Labor Force Survey; shares are over the employees of each group. Back to [Section 3](#).

Table A.2: Triple interaction coefficient using placebo outcomes

	Discharges by primary diagnosis						
	Heat (1)	Cardio (2)	Resp. (3)	G.u. (4)	Inj. (5)	Intox. (6)	Total (7)
<i>Panel A: Extensive margin (indicator)</i>							
$D_{pym}^{>35} \times \text{Post} \times \text{HiUndoc}$	-0.033** (0.016)	—	—	—	—	0.004 (0.011)	—
Outcome mean	0.238	1.000	1.000	1.000	1.000	0.904	1.000
Outcome SD	0.426	0.000	0.000	0.000	0.000	0.295	0.000
Obs.	2820	2820	2820	2820	2820	2820	2820
<i>Panel B: Intensive margin (asinh)</i>							
$D_{pym}^{>35} \times \text{Post} \times \text{HiUndoc}$	-0.020 (0.023)	0.003 (0.005)	-0.010 (0.009)	-0.005 (0.007)	0.001 (0.006)	0.023 (0.023)	-0.001 (0.002)
Outcome mean	0.284	5.557	5.588	5.666	5.849	2.247	8.435
Outcome SD	0.560	1.075	0.978	0.983	1.059	1.200	0.991
Obs.	2820	2820	2820	2820	2820	2820	2820
Year $\times$ Month FE	✓	✓	✓	✓	✓	✓	✓
Prov $\times$ Month FE	✓	✓	✓	✓	✓	✓	✓
Full Controls	✓	✓	✓	✓	✓	✓	✓
Linear + Quadratic trends	✓	✓	✓	✓	✓	✓	✓
May-Sep only	✓	✓	✓	✓	✓	✓	✓

Note: This table presents the estimates of the parameters from [equation \(1\)](#) using discharges unrelated to heat as placebo outcomes. Each cell reports the coefficient on $D_{pym}^{>35} \times \text{Post}_{ym} \times \text{HiUndoc}_p$ from a separate regression with the specification of column 4 of Table 1. Outcomes are discharges of working-age patients whose primary diagnosis is heat-related (column 1), cardiovascular (column 2), respiratory (column 3), genitourinary (column 4), an injury (column 5) or an intoxication (column 6), and all discharges excluding heat-related ones (column 7). In Panel A, the outcome is an indicator for at least one discharge in the province-month; “—” marks outcomes that are positive in every province-month, for which the indicator is constant and the regression is not defined. In Panel B, the outcome is the inverse hyperbolic sine of the number of discharges. Controls include population (total and migrant) in 2003 and 2004, unemployment rate, employment in part-time, permanent, public, agricultural and hospitality jobs, average wage, days worked in 2004 and a coastal dummy. Standard errors are clustered at the province level. Back to Section 5.

Table A.3: Placebo estimates by age of the patient

	Patient age		
	15–64 (1)	0–14 (2)	65+ (3)
$D_{pym}^{>35} \times \text{Post} \times \text{HiUndoc}$	-0.033** (0.016)	-0.002 (0.011)	-0.002 (0.011)
Year $\times$ Month FE	✓	✓	✓
Prov $\times$ Month FE	✓	✓	✓
Full Controls	✓	✓	✓
Linear + Quadratic trends	✓	✓	✓
May-Sep only	✓	✓	✓
Outcome mean	0.238	0.064	0.162
Outcome SD	0.426	0.245	0.369
Obs.	2820	2820	2820

Note: This table presents the estimates of the parameters from [equation \(1\)](#) separately by age of the patient. Each column uses the specification of column 4 of Table 1, with an indicator for at least one heat-related discharge of a patient in the given age range as the outcome. Column 1 reproduces our main estimate for working-age individuals (15–64), while columns 2 and 3 use children (0–14) and the elderly (65 and older), respectively. Controls include population (total and migrant) in 2003 and 2004, unemployment rate, employment in part-time, permanent, public, agricultural and hospitality jobs, average wage, days worked in 2004 and a coastal dummy. Standard errors are clustered at the province level. Back to [Section 5](#).

Table A.4: Robustness estimates

	Binary		Continuous	
	(1)	(2)	(3)	(4)
$D_{pym}^{>35} \times \text{Post} \times \text{HiUndoc}$	-0.033** (0.016)			
$D_{pym}^{>35} \times \text{Post} \times \text{HiAgriUndoc}$		-0.030** (0.015)		
$D_{pym}^{>35} \times \text{Post} \times \text{ShUndoc}_p$			-1.166** (0.462)	
$D_{pym}^{>35} \times \text{Post} \times \text{ShareAgriUnd}$				-7.645*** (2.677)
Year $\times$ Month FE	✓	✓	✓	✓
Prov $\times$ Month FE	✓	✓	✓	✓
Full Controls	✓	✓	✓	✓
Linear + Quadratic trends	✓	✓	✓	✓
May-Sep only	✓	✓	✓	✓
R2	0.389	0.390	0.392	0.390
Obs.	2820	2820	2820	2820

Note: Controls include population (total and migrant) in 2003 and 2004, unemployment rate, employment in part-time, permanent, public, agricultural and hospitality jobs, average wage, days worked in 2004 and a coastal dummy. The outcome is an indicator for any heat-related discharge of working-age individuals. Standard errors are clustered at the province level. Back to Section 5.

Table A.5: Main results excluding Madrid and Barcelona

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) Logit
$D_{pym}^{>35}$	0.020*** (0.006)	0.002 (0.007)	0.011 (0.011)	0.013 (0.015)	0.098 (0.060)
$D_{pym}^{>35} \times \text{Post}$	0.005 (0.006)	0.010 (0.007)	0.010 (0.008)	0.001 (0.014)	0.044 (0.078)
$\text{Post} \times \text{HiUndoc}$	-0.008 (0.037)	-3.239 (2.618)	53.756* (28.874)	27.590 (61.416)	-11.626 (41.725)
$D_{pym}^{>35} \times \text{Post} \times \text{HiUndoc}$	-0.025** (0.010)	-0.027** (0.011)	-0.026** (0.012)	-0.035** (0.016)	-0.207** (0.083)
Year $\times$ Month FE		✓	✓	✓	✓
Prov $\times$ Month FE			✓	✓	
Full Controls		✓	✓	✓	✓
Linear + Quadratic trends			✓	✓	
May-Sep only				✓	
R2	0.241	0.287	0.388	0.374	
Pseudo R2					0.316
Obs.	6480	6480	6480	2700	4620

Note: This table presents the estimates of the parameters from [equation \(1\)](#), excluding the provinces of Madrid and Barcelona. Columns 1 to 5 replicate the specifications in columns 1 to 5 of [Table 1](#). Column 1 includes only province fixed effects. Column 2 adds year-month fixed effects and pre-arrest province-level controls. Column 3 adds province-month fixed effects as well as province-specific linear and quadratic trends. Column 4 restricts the sample to the warm season (May–September). Column 5 presents the coefficients from a logit model including the full set of climatic and labor market controls, as well as province and year-month fixed effects. Controls include population (total and migrant) in 2003 and 2004, unemployment rate, employment in part-time, permanent, public, agricultural and hospitality jobs, average wage, days worked in 2004 and a coastal dummy. The outcome is an indicator for any heat-related discharge of working-age individuals. Standard errors are clustered at the province level. [Back to Section 5](#).

Table A.6: Main results excluding January to May 2005

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) Logit
$D_{pym}^{>35}$	0.020*** (0.006)	0.002 (0.007)	0.010 (0.011)	0.014 (0.015)	0.081 (0.057)
$D_{pym}^{>35} \times \text{Post}$	0.005 (0.006)	0.010 (0.007)	0.011 (0.008)	-0.003 (0.014)	0.060 (0.075)
$\text{Post} \times \text{HiUndoc}$	0.010 (0.038)	-4.556** (2.152)	14.586 (32.348)	23.414 (51.762)	-37.720 (36.720)
$D_{pym}^{>35} \times \text{Post} \times \text{HiUndoc}$	-0.022** (0.011)	-0.023** (0.011)	-0.022* (0.012)	-0.030* (0.017)	-0.182** (0.078)
Year $\times$ Month FE		✓	✓	✓	✓
Prov $\times$ Month FE			✓	✓	
Full Controls		✓	✓	✓	✓
Linear + Quadratic trends			✓	✓	
May-Sep only				✓	
R2	0.258	0.303	0.405	0.390	
Pseudo R2					0.334
Obs.	6533	6533	6533	2773	4968

Note: This table presents the estimates of the parameters from [equation \(1\)](#), excluding the rollout period of the amnesty program (January to May 2005). Columns 1 to 5 replicate the specifications in columns 1 to 5 of [Table 1](#). Column 1 includes only province fixed effects. Column 2 adds year-month fixed effects and pre-amnesty province-level controls. Column 3 adds province-month fixed effects as well as province-specific linear and quadratic trends. Column 4 restricts the sample to the warm season (May–September). Column 5 presents the coefficients from a logit model including the full set of climatic and labor market controls, as well as province and year-month fixed effects. Controls include population (total and migrant) in 2003 and 2004, unemployment rate, employment in part-time, permanent, public, agricultural and hospitality jobs, average wage, days worked in 2004 and a coastal dummy. The outcome is an indicator for any heat-related discharge of working-age individuals. Standard errors are clustered at the province level. Back to [Section 5](#).

Table A.7: Main results using the share of undocumented non-EU migrants

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) Logit
$D_{pym}^{>35}$	0.020*** (0.006)	0.002 (0.007)	0.010 (0.011)	0.016 (0.015)	0.004 (0.015)	0.089 (0.055)
$D_{pym}^{>35} \times \text{Post}$	0.005 (0.006)	0.010 (0.007)	0.010 (0.008)	-0.006 (0.014)	0.003 (0.014)	0.024 (0.070)
$\text{Post} \times \text{HiUndoc (NonEU)}$	-0.009 (0.038)	-3.637 (2.373)	17.564 (31.962)	-14.232 (59.036)		-29.650 (38.262)
$D_{pym}^{>35} \times \text{Post} \times \text{HiUndoc (NonEU)}$	-0.021* (0.011)	-0.023** (0.011)	-0.022* (0.012)	-0.028 (0.017)		-0.166** (0.077)
$D_{pym}^{>35} \times \text{Post} \times \text{ShareUnd (NonEU)}$					-1.304** (0.540)	
Year $\times$ Month FE		✓	✓	✓	✓	✓
Prov $\times$ Month FE			✓	✓	✓	
Full Controls		✓	✓	✓	✓	✓
Linear + Quadratic trends			✓	✓	✓	
May-Sep only				✓	✓	
R2	0.256	0.300	0.402	0.389	0.392	
Pseudo R2						0.333
Obs.	6768	6768	6768	2820	2820	5106

Note: This table presents the estimates of the parameters from [equation \(1\)](#) when we measure exposure using the share of undocumented non-EU migrants in the population in 2004. Columns 1 to 4 replicate the specifications in columns 1 to 4 of Table 1, replacing the undocumented-share indicator with an indicator for provinces with an above-median share of undocumented non-EU migrants. Column 5 uses the same specification as column 4 but with the continuous share of undocumented non-EU migrants as the exposure measure. Column 6 presents the coefficients from a logit model including the full set of climatic and labor market controls, as well as province and year-month fixed effects. Controls include population (total and migrant) in 2003 and 2004, unemployment rate, employment in part-time, permanent, public, agricultural and hospitality jobs, average wage, days worked in 2004 and a coastal dummy. The outcome is an indicator for any heat-related discharge of working-age individuals. Standard errors are clustered at the province level. Back to Section 5.

Table A.8: Difference-in-differences estimates on the sectoral shares of migrant employees

	Share of migrant employees in:							
	Agriculture	Construction	All other sectors	Components of all other sectors				
				Manufacturing and energy	Trade and hospitality	Transport, finance, business	Public admin., education, health	Other services (incl. domestic)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post $\times$ HiAgriUndoc	-0.051** (0.023)	-0.006 (0.028)	0.058** (0.027)	0.003 (0.036)	-0.037 (0.028)	0.013 (0.019)	0.015 (0.016)	0.064* (0.037)
Year $\times$ Quarter FE	✓	✓	✓	✓	✓	✓	✓	✓
Prov $\times$ Quarter FE	✓	✓	✓	✓	✓	✓	✓	✓
Full Controls	✓	✓	✓	✓	✓	✓	✓	✓
Outcome mean	0.103	0.174	0.723	0.155	0.210	0.080	0.060	0.219
Outcome SD	0.143	0.132	0.180	0.148	0.129	0.082	0.091	0.162
Obs.	2211	2211	2211	2211	2211	2211	2211	2211

Note: This table presents the coefficients from separate regressions of the share of migrant employees in each sector on $Post_t \times HiAgriUndoc_p$, with province-quarter and year-quarter fixed effects and pre-amnesty (2004) province-level controls interacted with $Post_t$, using the quarterly Spanish Labor Force Survey. Columns 1 to 3 add up to one, and columns 4 to 8 are the components of column 3 and add up to it. The survey's one-digit activity classification does not separate hospitality from retail trade, or domestic service from other services. Controls include population (total and migrant) in 2003 and 2004, unemployment rate, employment in part-time, permanent, public, agricultural and hospitality jobs, average wage, days worked in 2004 and a coastal dummy. Standard errors are clustered at the province level. Back to Section 6.

Table A.9: Placebo estimates using labor inspections

	(1) Main	(2) Inspections	(3) Inspections	(4) Horse Race	(5) Horse Race
Days > 35°C	0.012 (0.015)	0.014 (0.014)	0.023 (0.017)	0.013 (0.014)	0.014 (0.016)
Days > 35°C × Post	-0.001 (0.014)	-0.006 (0.014)	-0.006 (0.016)	-0.004 (0.013)	0.001 (0.014)
Days > 35°C × Post × High Exposure	-0.033** (0.016)			-0.038* (0.019)	-0.034** (0.015)
Days > 35°C × Post × High Inspections 2004		-0.010 (0.019)		0.008 (0.018)	
Days > 35°C × Post × High Inspections 2005			-0.020 (0.022)		-0.006 (0.014)
Year × Month FE	✓	✓	✓	✓	✓
Prov × Month FE	✓	✓	✓	✓	✓
Full Controls	✓	✓	✓	✓	✓
Linear + Quadratic trends	✓	✓	✓	✓	✓
May-Sep only	✓	✓	✓	✓	✓
R2	0.389	0.389	0.386	0.393	0.393
Obs.	2820	2820	2820	2820	2820

Note: This table presents placebo and horse-race estimates of the parameters from [equation \(1\)](#) using labor inspections. Column 1 presents the results from our main specification as reported in column 4 of Table 1. Columns 2 and 3 replace the undocumented-share indicator with indicators for provinces at or above the cross-province median number of labor inspections in 2004 and 2005, respectively. Columns 4 and 5 include both the main triple interaction and a parallel triple interaction with inspections measured in 2004 and in 2005, respectively. Controls include population (total and migrant) in 2003 and 2004, unemployment rate, employment in part-time, permanent, public, agricultural and hospitality jobs, average wage, days worked in 2004 and a coastal dummy. The outcome is an indicator for any heat-related discharge of working-age individuals. All columns use May–September only. Standard errors are clustered at the province level. Back to [Section 6](#).

Table A.10: Difference-in-differences estimates on discharges by diagnosis (asinh)

	(1) Heat	(2) Cardio	(3) Resp.	(4) G.u.	(5) Inj.	(6) Intox.	(7) Total
Post $\times$ HiUndoc	-0.001 (0.040)	0.023 (0.048)	-0.014 (0.039)	-0.012 (0.046)	0.189* (0.112)	-0.419** (0.190)	0.017 (0.024)
Year $\times$ Month FE	✓	✓	✓	✓	✓	✓	✓
Prov $\times$ Month FE	✓	✓	✓	✓	✓	✓	✓
Full Controls	✓	✓	✓	✓	✓	✓	✓
Linear + Quadratic trends	✓	✓	✓	✓	✓	✓	✓
R2	0.438	0.979	0.977	0.977	0.967	0.768	0.997
Obs.	6768	6768	6768	6768	6768	6768	6768

Note: This table presents difference-in-differences estimates comparing provinces with high and low exposure to the amnesty, before and after the reform, without the interaction with extreme heat. Each column reports the coefficient on $Post_{ym} \times HiUndoc_p$ from a separate regression in which the outcome is the asinh of the number of discharges with a given primary diagnosis: heat-related (column 1), cardiovascular (column 2), respiratory (column 3), genitourinary (column 4), injuries (column 5), intoxications (column 6), and all discharges excluding heat-related ones (column 7). Controls include population (total and migrant) in 2003 and 2004, unemployment rate, employment in part-time, permanent, public, agricultural and hospitality jobs, average wage, days worked in 2004 and a coastal dummy. All columns use the full sample of months. Standard errors are clustered at the province level. Back to [Section 6](#).