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Blame it on the Rain: The Effects of Weather Shocks on Formal Rural Employment in Colombia

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Abstract

Episodes of excessive or low rainfall have not only become more frequent, but also more severe. These events can affect agricultural production and local labor markets. By combining social security records, that allow us to measure formal employment, with administrative data from weather stations, we estimate the effects of municipality-level precipitation shocks on formal rural employment in Colombia, as well as country-wide events like El Niño and La Niña phenomena. Fixed effects estimates show that episodes of excessive rainfall—measured as those that are above the 80th percentile of historical mean precipitation in the last 30 years for each municipality—have a negative impact on formal employment in rural areas for both the agricultural and non-agricultural sector, ranging from -2.2 percent to -3 percent, respectively. Likewise, we find that both El Niño and La Niña phenomena have a negative impact on total formal employment in rural areas. Additionally, we explore if the effect of rain shocks varies depending on the access to irrigation and drainage technologies, finding that municipalities with high prevalence of irrigation systems are less affected by episodes of low rainfall.

Keywords: Formal labor market, employment, weather shocks, agriculture, Colombia
JEL Classification: J20, J30, J43, J46, Q54, R23

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Culpar a la Lluvia: Los Efectos de los Choques Climáticos Sobre el Empleo Formal Rural en Colombia

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Resumen

Los episodios de excesiva o poca precipitación no solo se han vuelto más frecuentes sino que cada vez son más severos. Estos eventos pueden afectar la producción agrícola y las dinámicas de los mercados laborales locales. Combinando registros de seguridad social, que nos permiten identificar empleo formal, con datos administrativos de las estaciones meteorológicas, estimamos los efectos de los choques de lluvia a nivel municipal sobre el empleo formal rural en Colombia, al igual que el impacto de los fenmenos de El Niño y La Niña. Los estimadores de efectos fijos muestran que los episodios de excesiva precipitación, medidos como aquellos que se ubican por encima del percentil 80 de la distribución histórica para cada municipio, tienen un impacto negativo sobre el empleo formal rural tanto para el sector agrícola como para el no agrícola, ubicándose entre -2.2 y -3 por ciento, respectivamente. De igual forma, encontramos que los fenómenos de El Niño y La Niña tienen un impacto negativo sobre el empleo formal rural. Adicionalmente, exploramos si el efecto de los choques de lluvia depende del acceso a sistemas de riego, encontrando que municipios con alta incidencia de estos mecanismos de irrigación son menos propensos a verse afectados por episodios de poca precipitación.

Palabras clave: Mercado laboral formal, empleo, choques climáticos, agricultura, Colombia
Clasificación JEL: J20, J30, J43, J46, Q54, R23

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1 Introduction

Households located in rural areas in developing countries are exposed to a handful of shocks, such as conflict, crop plagues, droughts, and natural disasters. All of them have the potential to affect their productivity, employment opportunities, and, consequently, exacerbate poverty (Jayachandran, 2006; Quinones, 2018). Colombian rural households are not exempt of these risks, as the large body of evidence on the effects of the conflict on agricultural production, rural labor markets and internal displacement shows (Fernández, Ibáñez, and Peña, 2014; Calderón-Mejia and Ibáñez, 2016).

In addition to violence, rural households are also exposed to the effects of climate change. In fact, as a consequence of the cooling and warming patterns of the Pacific Ocean, countries located near the Equator such as Colombia, that only have two seasons—dry and rainy, experience every few years intense rainy periods and longer than usual dry summer seasons, known as "Fenómeno de la Niña" and "Fenómeno del Niño", respectively (Sanchez-Jabba et al., 2014).

Unexpected rain patterns could act as negative productivity shocks which could cause large changes in wages and employment opportunities, especially when workers are poorer, less able to migrate, and more credit-constrained because they face an inelastic labor supply curve (Jayachandran, 2006). For example, between 2010-2011, Colombia underwent the worst episode of La Niña phenomenon of recent times. As a result of the prolonged rain, there were several floods that dramatically hit municipalities located on the margins of the main rivers of the country. This natural disaster affected approximately 7% of the population of the country and 80% of the municipalities (Sanchez-Jabba et al., 2014). On the other end, during 2015-2016, the country experienced a severe El Niño episode—or extended dry season—that left the Magdalena River, which is the main river that crosses the country, at its lowest historical levels and more than half of the municipalities of the country experienced water scarcity and fires.

The negative impact of unexpected rain shocks depends on when they happen during the crops cycle. If there is rain during harvest season, then the crops could be damaged. But if there is no rain during the seed sowing and irrigation season, in particular in areas where there are no irrigation systems, then the crops are going to have a poor performance. Thus, predictable rain patterns are necessary for agricultural production as farmers need to plan accordingly. Therefore, bad weather shocks can potentially lower agricultural labor productivity as they lower crops' yield (Chaurey, 2015; Adhvaryu, Chari, and Sharma, 2013).

Rain shocks can also translate into less available employment and lower wages as there is a reduced demand for labor at harvest time assuming that the labor supply remains unchanged. This situation is very frequent in poor rural communities as they live at the subsistence level and do not have access to smoothing mechanisms such as the credit market or migration that could help them reduce the quantity of labor they are supplying to the labor market when wages are low. Instead, in their case, the income effect dominates the substitution effect and they end up supplying even more labor to compensate the drop in earnings (Jayachandran, 2006).

We estimate the effect of rain shocks, defined as episodes of monthly precipitation that are above the 80th percentile or below the 20th percentile of mean precipitation in the last 30 years for each municipality, on formal employment and earnings of workers located in rural areas in Colombia. We define formal workers as those who make monthly contributions to the social security system (health and pensions). We mainly focus on formal workers as we would like to understand one of the mechanisms that could be negatively impacting the creation of formal jobs in rural areas, given that informality is one of the main issues of rural labor markets in Colombia (Leibovich et al., 2006; Merchán et al., 2015; Otero-Cortés, 2019). We also aim to determine if there are heterogeneous effects depending on the sign of the rain shock, based on our definition of shocks exposed before, and how wages and formal employment adjust in the presence of each type of shocks.

We use two different sources of administrative data to construct our databases. First, we use data from the Colombian Institute of Hydrology, Meteorology and Environmental Studies (IDEAM for its acronym in Spanish), which contains daily data on rainfall and temperature for more than 2,000 weather stations in the country. Additionally, we use the Integrated Register of Social Security Contributions (PILA for its acronym in Spanish), which contains the universe of the mandatory monthly contributions to the social security system of all formal workers in the country. We combine both sources of data to create a rich and novel municipality-level database that allows us to follow about 72% of all rural municipalities in Colombia for the period 2008–2018. We also use data from the Colombian Household Survey (GEIH), which contains representative information about workforce indicators and socio-economic characteristics for the whole country—including rural areas, and it allows us to characterize the informal labor market.

Our preliminary results display a consistent negative effect of excess of rainfall episodes (i.e., above the 80th percent of its historical mean) on formal employment. Regarding earnings, the negative impact takes place mainly for non-agricultural jobs. These results aim to confirm that episodes with excessive rainfall can be considered negative productivity shocks. After estimating our regression model for sub-samples of municipalities with the same agricultural orientation (i.e., their most farmed crop is the same), we find that maize and potato-oriented municipalities are probably the most affected by rainfall shocks. Potato and maize productions are far from being comparatively competitive in Colombia, which we suspect they are more prone to experience decreases in yield due to extreme weather events due to the lack of technology for coping with those episodes.

This paper aims to contribute to the literature on adaptation to climate change (Kochar, 1999; Mueller and Osgood, 2009; Dillon, Mueller, and Salau, 2011; Loayza et al., 2012; Jessoe, Manning, and Taylor, 2018; Quinones, 2018; Brey and Hertweck, 2019; Burzyński et al., 2019; Maitra and Tagat, 2019) as we study how one of the mitigation mechanisms available to producers, such as quantity of employment hired, responds to unexpected productivity shocks due to changes in rain patterns. This paper also adds to the existing literature on informality and labor market regulation in developing countries as in Almeida and Carneiro (2012), Meghir, Narita, and Robin (2015), Ulyssea and Ponczek (2018), and Ulyssea (2020). Another relevant feature of this study, as displayed by the regression estimates, points out that episodes of excessive rainfall do not necessarily correspond to positive shocks on agricultural production, as the literature for India or Southeast Asia has already found (Jayachandran, 2006). Geographic, orographic, and pluviometric conditions vary by countries or regions and, thus, the effect of rainfall shocks across them do not have to be homogeneous.

2 Background and Data

In this section, we provide a brief description of the regulation that defines labor formality in Colombia. Then, we discuss some theoretical aspects of the effects of agricultural productivity shocks on the (formal and informal) labor market. Then, we characterize the most important rainfall patterns in Colombia. Last, but not least, we describe the data used in this paper.

2.1 Labor Regulation in Colombia and Informality

There are different definitions of formality that depend on the available data and labor regulation of each country. In our case, we will use a legalistic definition based in the Colombian Labor Code that allows us to measure formality in a more strict way than traditional measures such as size of the firm.[1] A worker is classified as formal in two cases. If the worker is an employee, then both the employee and the employer must make monthly mandatory contributions to health care and pensions. Every month, the employee contributes 8 percent of her monthly wage for social security (4 percent to health care and pensions each one), while the employer contributes 8.5 percent to the health care account and 12 percent to the pensions account of the employee, based on her monthly wage. If the worker is self-employed or independent, then she must pay 100 percent of the social security contributions by herself (12 percent of her earnings go to health contributions and 16 percent of her earnings go to pensions). In the agricultural labor market, day-laborers are still common and they should also comply with the labor law as if they were self-employed or independent workers.

In the case of a dependent working relationship, the employer must also comply with other regulations mandated by the Labor Code such as the national minimum wage, severance payment, payroll taxes, once a year paid vacation time, and end-of-the-year bonus, among others. During our period of interest, 2008–2016, there was a tax reform at the end of 2012 that cut down by 5 percent points the non-wage costs associated to formal employment. Thus, between 2008-2012, all these non-salary costs summed up to 52.3 percent of the wage of the worker and after the 2012 tax reform they represented 47.3 percent of the average wage of the workers. Overall, it is fair to say that formal employment is costly in monetary

[1]For documents using contributions to social security as definition of informality, see: Pratap and Quintin (2006) and Bobba, Flabbi, and Levy (2018). For papers using firm size as a measure of informality, see: Tannuri-Pianto et al. (2004). For papers using a legalistic measure of informality, see: Almeida and Carneiro (2012), Meghir, Narita, and Robin (2015), and Ulyssea and Ponczek (2018).

terms, but also in time as hiring a formal worker requires some paper-work that must be done by the employer of by the worker if she is self-employed that is time-consuming. It is important to point out that there is not such a thing as a general unemployment insurance in Colombia when workers are laid off. Formal workers are entitled to a "severance package", but informal workers do not receive any form of monetary or non-monetary payments when they lose their jobs.

Enforcement of the labor code was not very stringent particularly before 2013 as there were very few labor inspections officers in the main cities of Colombia, and even less in small rural areas. Thus, for the inspectors was hard to verify the compliance of the worker and employer with the labor code and it was also hard for the workers to report a violation to their rights because they would have have to travel to a larger city in order to be able to go to an inspection office.

2.2 Conceptual Framework

As we are only focusing on rural municipalities, we assume for simplicity purposes that the rural economy is composed of two sectors: agriculture (A), that absorbs more than 50 percent of the workers in rural areas, (according to our data), and Other (O), mostly comprised by mining and small commercial business. Inside each sector, there is a formal and an informal labor market. On average, workers who work in the formal labor market are more skilled than workers in the informal labor market. Household-level data shows that there is a higher proportion of workers with primary school or less working informally than in formal jobs (one third of high-skilled workers -defined as having reached an education level of middle school or higher- work informally and 2/3 of high-skilled workers work formally, based on our definition of formality).[2]

The formal labor market is the one in which workers and their employers—in case they work for someone else—and self-employed individuals as well have to make contributions to social security and, additionally, need to comply with the current labor regulation such as the mandated national minimum wage. Therefore, formal employees cannot earn less than the minimum wage by definition. Nevertheless, informal jobs are very common in rural areas. Moreover, one could expect to find more informal workers than formal for several reasons: first, not enough enforcement of labor regulations in rural areas. Second, the nature and characteristics of agricultural production (e.g., weather uncertainty, lack of credit access, poor road and utilities infrastructure, high non-labor input costs): Last, but not least, low reservation wages for most of rural workers. All these factors together make informal job more preferred than being unemployed or out of the labor force.

In the formal labor market, the existence of a minimum wage can cause a mismatch between the quantities of formal labor demanded and supplied at both sectors if the minimum wage is binding. More precisely, one could expect that the quantity of formal labor demanded would be less than the quantity of formal labor supplied if the minimum wage is significantly higher than the equilibrium wage. In such scenario, the workers who wanted to get a formal job in one of the two sectors, let's say in sector A, and could not get it, may have incentives to switch to the informal labor market in sector A and accept a lower-paying informal job instead of searching for a job in the formal labor market in sector O, as most of the formal workers' skills within sector A may not be transferable to sector O. As stated by the literature, there is evidence about the informal labor market acting as a buffer to reduce adjustment costs in the labor market due to shocks (Ulyssea and Ponczek, 2018), as the informal labor market does not need to comply with labor laws, there are no formal written

[2] Ulyssea and Ponczek (2018) also finds a similar behavior for Brazil.

contracts, employers do not face high hiring or firing costs and wages can be adjusted as necessary, even below the minimum wage during negative productivity shocks.

If an unexpected negative productivity shock takes place in the agricultural sector, this causes a contraction of both the formal and informal labor demand as agricultural production should decrease. As a consequence, formal wages in the agricultural sector would need to adjust but they can only fall up to the minimum wage, causing an increase in unemployment, while in the informal labor market the new equilibrium wage will be determined by the intersection of the shifted labor demand and the labor supply curve that remains unchanged. In summary, we expect that a negative productivity shock will decrease wages and employment in the formal labor market in the agricultural sector, but this does not necessarily cause an spike in unemployment as these newly laid-off workers can switch to the informal labor market.

This productivity shock in agriculture also has consequences in the other sector. First, a decrease in wages and employment in the formal agricultural sector implies that workers have less available income and they would demand less goods and services from agriculture and the other sector as well. Therefore, one can also expect a similar adjustment in both labor markets in the other sector: a decrease in employment and lower formal wages.

On the other hand, an unexpected positive productivity shock in the agricultural sector would shift to the right the labor demand curve, for both formal and informal workers in this sector, if there are no short-term changes in labor supply. But the effect on wages is ambiguous: if the minimum wage is binding in the formal labor market before the shock, then the effect on formal wages would be 0 if the new equilibrium wage is still below the minimum wage or it could be positive if the new equilibrium wage is above the minimum wage. However, if the minimum wage was not binding, then the effect would be positive.

In the informal labor market, both wages and the quantity of labor demanded are expected to increase. In the aggregate, the magnitude of the effect on wages and total employment depends on the elasticity of the demand curve and if the minimum wage was binding or not.

2.3 Characterizing Rainfall Patterns in Colombia

According to the national meteorology authorities, Colombia is one of the most pluviometric-diverse nations in the world.[3] Being located near the Equator, its climate and weather characteristics resemble a tropical country, where temperature changes according to the altitude (i.e., no significant seasonal changes), and precipitation is the only event that really varies across time and location.[4]

The Colombian territory can be divided into five main groups regarding the intensity of precipitation across time. The Caribbean region, located at the north side of the country, is characterized of having two precipitation zones. The northern plains are generally arid. For this area, yearly average precipitation oscillates between 300 and 600mm.[5] The southern area of this region is known from being more humid and rainy due to the confluence of several main rivers. Yearly average precipitation rounds between 1,800 and 2,000mm. The Caribbean region experiences two well-defined rainy seasons throughout the year: the first one takes place between the months of April and June, while the second period occurs and between September and December.

The Andean region, situated across the main lands of the Andes range, the annual average intensity of rainfall varies between 2,000 and 4,000mm. The difference in precipitation level within the region slightly varies by latitude. The driest season takes place during mid-year

[3] `http://atlas.ideam.gov.co/cclimatologicas/info/lluviamen.html`, consulted on April 28, 2020.
[4] `https://www.britannica.com/place/Colombia`, accessed on April 28, 2020
[5] One inch of rainfall represents 25mm.

for the southern area, whereas for the northern portion of this region the period with the lowest precipitation levels occurs during the months of December, January, and February. The Orinoquia region, located to the east of the Andes range, experience greater variation in precipitation across its area (between 1,500 and 6,000mm). Rainfall seasons are clearly defined: the rainiest period is the longest and takes place between late-March and November.

The Amazon and Pacific regions are the most exposed to longer and more intensive periods of precipitation. As in the Orinoquia, the Amazon regions experiences the wettest season between the months of April and November, with a yearly average precipitation that oscillates between 3,000 and 4,500mm. On the other hand, the Pacific region is considered as one of the rainiest areas in the world. Yearly average precipitation lies between 8,000 and 10,000mm, and it is harder to identify clear seasonal patterns in rainfall.

2.4 Data

We use three different sources of data. Regarding weather, our data come from the Colombian Institute of Hydrology, Meteorology and Environmental Studies (IDEAM for its acronym in Spanish), including information about rainfall and temperatures for more than 2,000 weather stations in the country. With respect to employment and wages, our data come from the Integrated Register of Social Security Contributions—PILA for its acronym in Spanish, which contains the universe of monthly mandatory contributions to the social security system of all formal workers in the country. Our time period of interest spans from 2008 to 2018. Merging the weather data with PILA generates an unbalanced panel that comprises 524 municipalities in rural areas, as displayed by Figure 1. The third source of data come from the Colombian Household Survey (GEIH in Spanish), the official source for employment statistics in Colombia. The GEIH allow us to identify movements out of formality (i.e., informality, unemployment, out-of-the-labor-force).

2.4.1 Weather Data

We use administrative records from IDEAM, which includes monthly information about total precipitation (in millimeters), number of days with rain, as well as the maximum amount of rainfall in a day of the current month. The IDEAM has collected weather data on rainfall and temperatures for $2,726$ stations since year 1900. It is important to remark that the number of stations has not been constant throughout the years: some have either been closed, moved to another location, or some new stations have been installed.

Our main weather measures correspond to a set of indicator variables equal to one whether the observed monthly amount of precipitation is at or above the 80th percentile, or at or below the 20th percentile of the historical distribution, for any given municipality. Other measures include monthly precipitation (in inches) for each municipality in our final sample, and indicator variables that are equal to one whether during month m of year t either El Niño or La Niña took place in Colombia. Our final database generates an unbalanced panel that comprises 524 municipalities in rural areas (about 86 percent of total rural municipalities in Colombia).

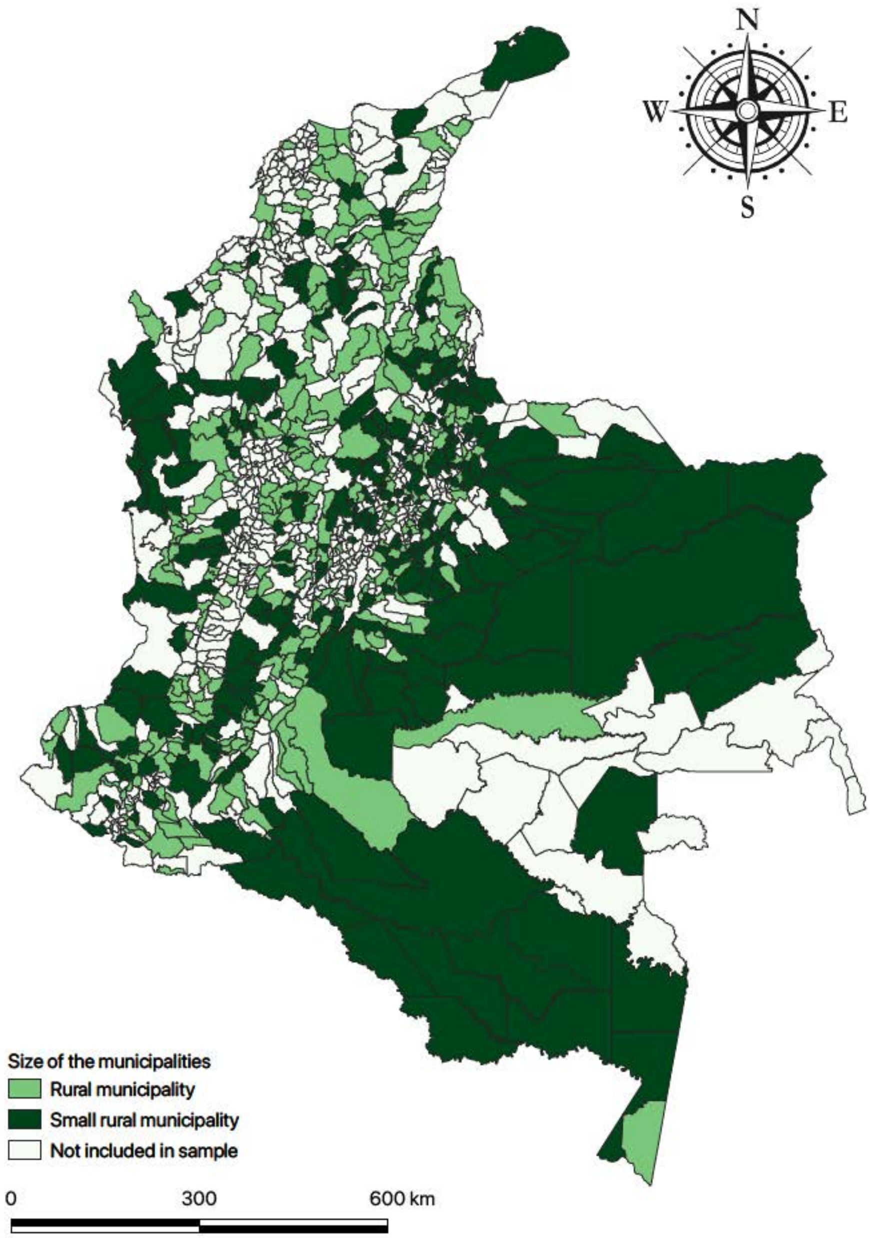


Figure 1: Municipalities Included in the PILA-weather merged data set

We estimate historical distributions of precipitation by using data for municipality i at month m for the last 30 years. This approach helps us to account for seasonality. For municipalities with more than one weather station, we compute the average rainfall from all stations at a given point in time t. To estimate monthly weather shocks between July 2008 and June 2018, we use historical data since 1979. For this period, we have rainfall data collected by $2,423$ unique stations. After accounting for re-locations, closures, and new installations, we have an average of $1,796$ stations per month–year. As reported by Table 1, larger municipalities by population are more likely to have more weather stations than their smaller counterparts. In Figure 2, we display the distribution of rainfall shocks across time. For this figure, we can observe that during our period of study (July 2008–June 2018), Colombia experienced more and longer episodes from La Niña than El Niño and, likewise, more monthly rainfall events when precipitation was above the 80th percentile

Table 1: Distribution of Weather Stations by Type of Municipality, 1979–2016

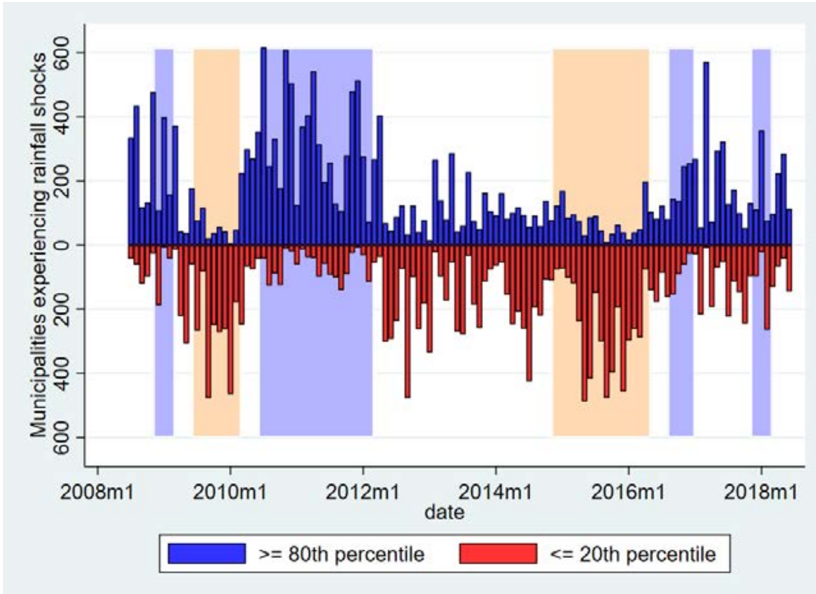
Municipal category	**No. of Stations**	**No. of Municipalities**	**Ratio**
Cities/conglomerates	306	83	3.69
Intermediate	430	209	2.06
Rural	568	269	2.11
Rural (disperse)	492	238	2.06

2.4.2 Employment Data

The PILA dataset includes information on pre-tax earnings, number of days worked, payroll taxes, and some demographic characteristics for the universe of formal workers in Colombia (i.e., those who pay contributions to health and pension) since July 2008. On average, there are approximately 8 million observations per month including urban workers, which account for the majority of formal employment in the country.

Using these records, we estimate the total monthly number of formal employment and the

Figure 2: Distribution of Rainfall Shocks, El Niño and La Niña Episodes, 2008–2018



Light blue areas corresponds to La Niña episodes, whereas light red areas refers to El Niño episodes. Source: Colombian Institute of Hydrology, Meteorology and Environmental Studies

average earnings for each municipality in our final sample. As Table 2 displays, the number of formal workers in rural areas has more than doubled between 2008 and 2018. However, formal employment in rural municipalities corresponds to a very small share of total formal employment in Colombia (around 15 percent), as stated by Otero-Cortés (2019). On average, formal rural workers earn 1.8 times the monthly minimum wage.

Our second data source for employment comes from the Colombian Household Survey. The GEIH is the main tool for studying the Colombian labor market and the characteristics of the workers. It is statistically representative of the rural areas of the country. For our period of interest, there were, on average, 4.5 million people working in the rural areas of Colombia. The labor force participation rate was, on average, 58 percent, and the unemployment rate, at 6.5 percent, was significantly lower (5 p.p.) than the one in the urban areas of Colombia.

Although informality is highly prevalent in the country as around half of the working

Table 2: Descriptive Statistics, Formal Rural Workers

	Employment		Wages		Share
Year	Mean	Std. dev.	Mean	Std. dev.	min. wage
2008	214,018.83	27,555.63	829,701.50	47,137.81	179.78
2009	258,431.75	23,840.34	866,770.75	46,971.92	177.89
2010	305,534.25	28,199.26	917,147.13	47,600.14	187.35
2011	329,577.92	41,356.11	932,943.13	42,356.89	190.08
2012	367,837.50	39,873.25	971,097.19	52,183.47	191.53
2013	384,680.33	40,584.73	990,135.88	55,676.56	191.33
2014	435,367.08	35,159.39	975,805.13	29,746.52	187.03
2015	455,007.92	32,949.53	953,142.81	30,251.50	186.46
2016	438,907.75	55,209.53	930,881.50	67,019.95	179.99
2017	496,506.42	56,640.20	953,303.56	87,463.29	179.30
2018	530,476.33	39,864.40	987,332.44	71,681.82	179.68

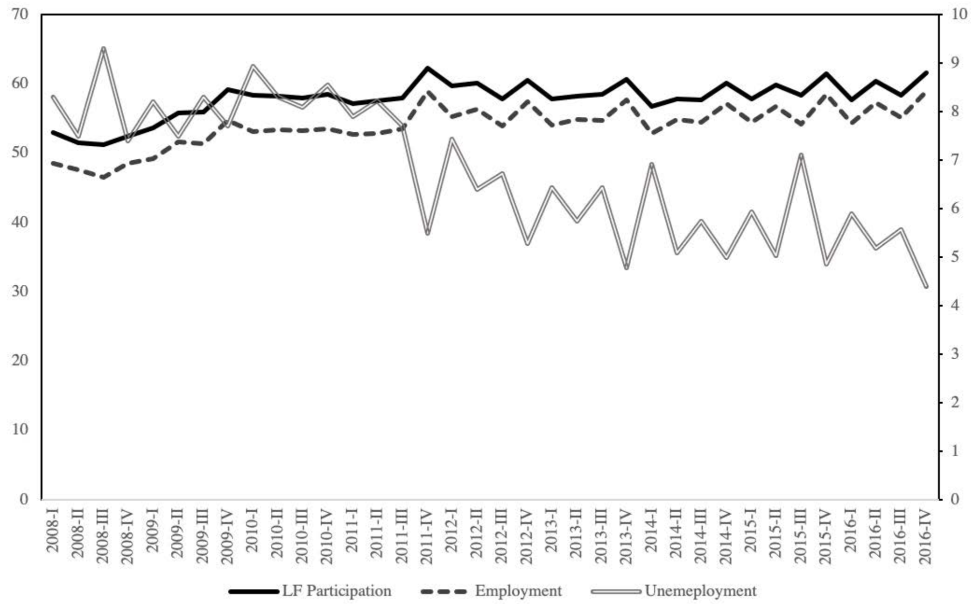
For both employment and wages, we display the monthly average value for each year. Wages are reported in 2008 constant prices. Source: PILA and IDEAM.

population does so informally, in the rural areas this proportion is even higher and sits at about 88 percent the total employment based on our definition of formality.

The main source of job opportunities in rural areas comes from the agricultural sector, in which, on average, 63 percent of individuals work, followed by the services and retail sector that hires, on average, 12 percent of the working population. On average, 49 percent of the workers in rural areas were self-employed during the period of interest, but this percentage has increased 10 p.p. in less than a decade and went from 43 percent in 2008 to 53 percent in 2016. Employees working at private firms represented 17 percent of total workers, while employees at public companies represented less than 2 percent across the whole period. The share of day-laborers went from 20 percent in 2008 to 11 percent in 2016. Unpaid labor in the household or in a family-owned business is common, thus, on average, 9 percent of the workers are unpaid. Entrepreneurship, on the other hand, is not as common and its share has fallen in period of interest from 5.1 percent to 3.8 percent.

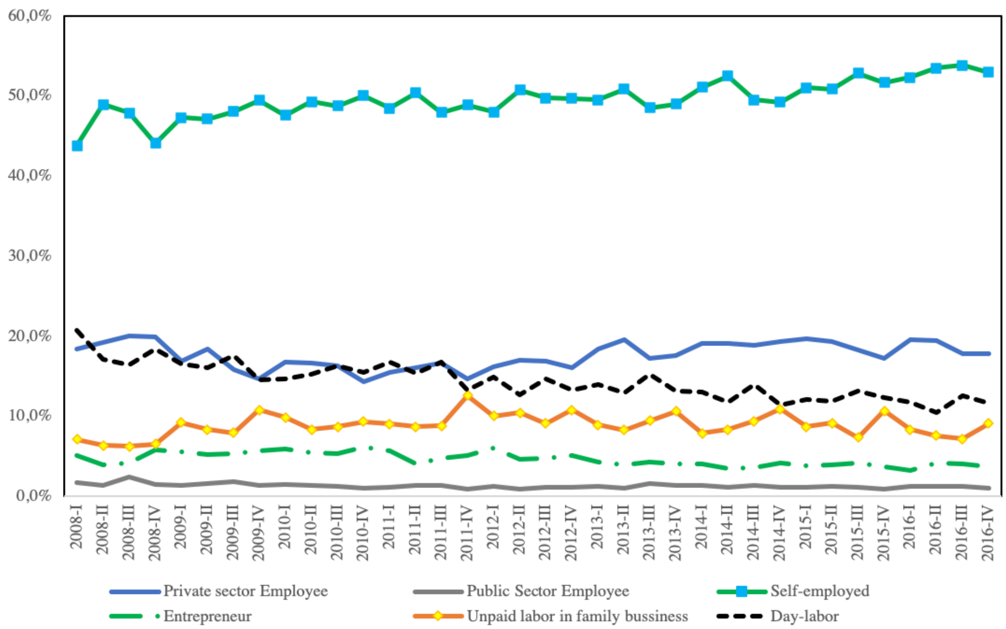
We also find that pensions and health contributions are highly seasonal as they increase

Figure 3: Labor Force Indicators for Colombia, 2008–2016



Source: Colombian GEIH

Figure 4: Occupations Distribution of Rural Workers in Colombia, 2008–2016



Source: Colombian GEIH

during the second and third quarter of the year and then they fall during the first and last quarter of the year. Regardless of that, in general, the formality rate has significantly increased throughout the period of interest, going from 10 percent, on average, for 2008 to 13.7 percent, on average, in 2013.

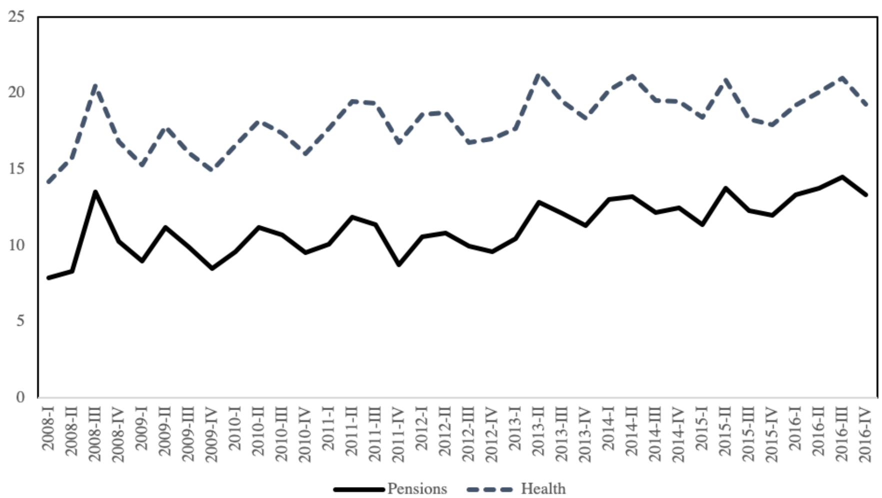
Earnings in the rural labor market are low when compared to the national minimum wage. Self-employed workers, which represent around 50% of the workers, have monthly earnings that are, on average, half a minimum wage. Public sector employees have the highest earnings, and also the fastest growing earnings, followed by employees from private companies. Day-laborers have earnings slightly below the minimum wage. Table 3 shows average monthly pre-tax earnings for formal and informal workers separately. Based on this, we find that formal workers do have earnings that are above the minimum wage, on average, but informal workers (this group represents more than 80% of the working population) have consistently lower earnings.

Table 3: Average monthly pre-tax earnings for formal workers and informal workers (in constant prices), 2008–2016

	Formal workers		Informal workers		Total	
Year	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
2008	757.933	669.724	262.797	392.284	312.611	447.866
2009	797.770	2.256.830	262.151	322.313	313.981	733.130
2010	800.835	1.139.977	262.541	336.206	318.839	508.211
2011	814.015	727.789	265.743	335.266	324.875	423.885
2012	843.918	1.720.591	265.267	357.616	326.775	644.952
2013	840.529	552.657	273.764	320.571	332.883	395.885
2014	859.085	706.793	275.999	324.333	344.732	449.607
2015	834.328	637.947	274.253	309.926	337.844	403.941
2016	838.249	675.106	281.132	313.330	353.182	422.031

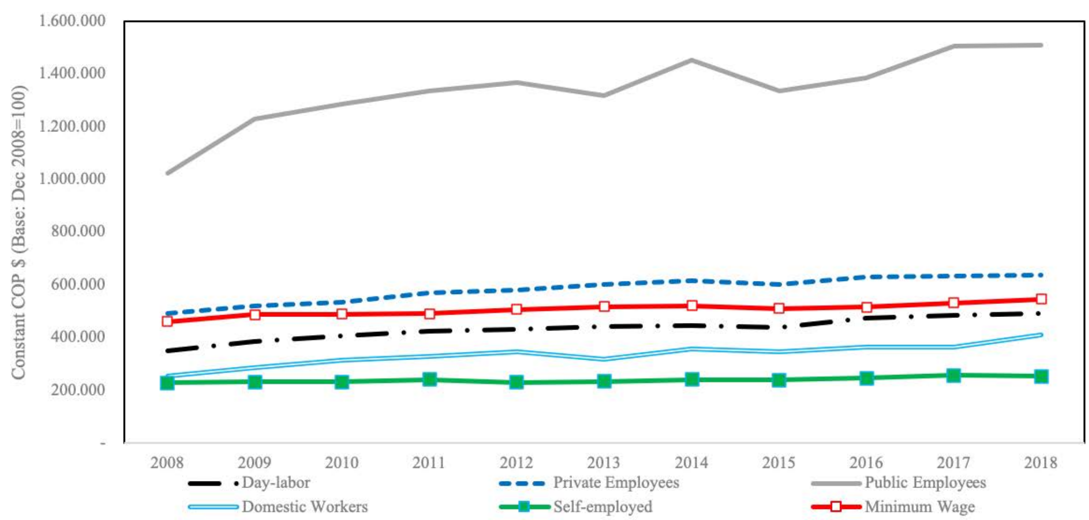
Source: Colombian GEIH

Figure 5: Share of Rural Workers Contributing to Social Security in Colombia, 2008–2016



Source: Colombian GEIH

Figure 6: Average Wages for Rural Workers by Occupation in Colombia, 2008–2016



Source: Colombian GEIH

3 Empirical Strategy

We follow Jayachandran (2006) by relying on municipality and month fixed-effect models to estimate the impact of weather shocks on formal employment and earnings. Our basic model accounts for the variation on the outcomes of interest and the weather measures described in Section 2.4.1 (total amount of precipitation, niño and niña indicators, and rain shocks as well):

$$log(Y_{imt}) = \beta_0 + \beta_1 W^{+}_{imt} + \beta_2 W^{-}_{imt} + \beta_3 W^{+}_{imt-1} + \beta_4 W^{-}_{imt-1} + \delta T + a_i + b_m + u_{imt} \quad (1)$$

where Y_{it} corresponds to the outcome of interest (total formal employment or average wages) in logarithms for municipality i in month m of year t, W^{+}_{imt}, W^{-}_{imt-1}, W^{-}_{imt}, and W^{-}_{imt-1} account for current and lagged realizations of our measures of rainfall of interest, respectively.[6] T is a yearly linear trend that accounts for the passage of time; a_i and b_m are the municipality and month fixed effects, respectively, and u_{imt} is a zero-mean error. From this model, the parameters of interest are β_1 to β_4, since they intend to capture the effect of current and past weather shocks on changes in formal unemployment or wages from their averages.

3.1 Identification

To claim a causal effect from our estimates, we need to ensure our explanatory variables are plausibly exogenous (i.e., no presence of unobserved heterogeneity, measurement error, or reverse causality). Regarding unobserved heterogeneity, time-invariant location-specific

[6] The inclusion of past realizations of precipitation events intend to account for the persistence of those episodes on current employment.

characteristics can also affect the impact of rain shocks on formal employment. As explained in Section 2.3, the Colombian geography is heterogeneous, embracing different altitudes, as well as varied precipitation and temperature zones. Consequently, either episodes of rainfall above or below historical means are expected to have a different effect depending on the affected area. Therefore, we include municipality-level fixed effects to account for location–based heterogeneity. Likewise, we also include month fixed effects to address unobserved time-variant characteristics. With respect to reverse causality, we do not expect it to be an issue. Our labor outcomes—formal employment and earnings—should not affect climate shocks.

Our main concern comes in the form of measurement error. Several aspects could exacerbate this issue. Although climate and formal employment data come from official registries, they are not entirely exempt from being wrongly measured. The presence of measurement error in the dependent variable implies that our regression estimates would remain unbiased, but with larger standard errors. To correct for that issue, we estimate our regression models with municipality-level clustered standard errors. Regarding weather, it is likely to expect that our data on precipitation is more accurate for larger municipalities, because they might count with more than one weather station, and they should be better equipped and maintained in comparison with those from smaller towns. As explained in Section 2.4, we count, on average, with more than two weather stations by municipality, for both rural and rural disperse categories. That allows us averaging precipitation data over time for most municipalities, helping us to increase accuracy on our explanatory variables by reducing the reliability of our measures on just one observation, helping us to significantly reduce measurement error.

4 Results

4.1 The effects on the Formal Labor Market

We begin with reporting the regression estimates of the effects of current (columns 1, 4, and 7 of panels a and b), lagged (columns 2, 5, and 8), and both present and past values (columns 3, 6, and 9) of precipitation on formal rural employment and wages, displayed in Table 4. It is no surprise that the magnitudes of the estimated coefficients are very small. But, these estimates are informative in the way that they show the direction of the effect of deviations of precipitation from its mean. With respect to changes in present levels, that effect is negative for total employment, but only for wages in the non-agricultural sector. Regarding lagged realizations of rainfall, we find a positive effect on both employment and wages, but only statistically significant for the non-agricultural sector.

Table 5 reports the estimates for Equation 2 using monthly indicators of rainfall above the 80th percentile (hereafter, AA shocks) and below the 20th percentile (hereafter, BA shocks) from its historical mean. Overall, current AA shocks are the only events that have a negative impact on formal rural employment and wages. Regarding employment, that effect lies between −3.0 (agricultural jobs) and −2.2 percent (non-agricultural jobs). With respect to wages, the estimates are about −1.2 percent for the agricultural sector and −1.3 percent for the non-agricultural sector. On the contrary, current BA shocks have a positive effect, principally in non-agricultural employment (1.7 percent) and wages (0.4 percent). The effect on the agricultural sector is positive but not statistically significant. With respect to lagged realization of rainfall shocks, we find mixed results. Past AA shocks have a negative effect on agricultural jobs (−2.0 percent), but a positive impact on the non-agricultural sector, on both employment (1.1 percent) and wages (0.4 percent). Regarding lagged BA shocks, the effect is positive for total employment and wages, but is not statistically significant on most of the regression models.

The estimates from Table 5 intend to capture the effect of municipality-specific rainfall shocks on formal rural labor market. Table 6 addresses the impact of El Niño and La Niña phenomena, which cover the entire nation. The regression model is the same as Equation 2, but we just replace the indicator variables for current (and lagged) positive of negative rainfall shocks for indicators that address whether in month t (and month $t-1$) either El Niño or La Niña took place.

From Table 6, we observe that current episodes of both El Niño and La Niña negatively affect employment. With respect to El Niño, that impact is about -2.1 percent, whereas for La Niña is over -6.1 percent, a much greater effect. Both events have some degree of persistence in the very short term. Lagged realizations of both El Niño and La Niña have a negative effect on agricultural employment (-4.2 and -6.9 percent, respectively), whereas the impact on the non-agricultural sector is positive (2.5 and 6.8 percent, respectively). Regarding wages, current episodes of La Niña have a clear negative impact on all sectors (an average of -2.8 percent), whereas lagged events have a positive effect (2.2 percent overall). On the other hand, we find an overall negative effect of both current and past El Niño episodes, but only statistically significant for the former at the non-agricultural sector (about -1.2 percent).

Table 4: The effect of monthly precipitation in the formal rural labor market

(a) Dependent variable: log(employment)

	Total			Agricultural			Nonagricultural		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year trend	0.096***	0.093***	0.093***	0.128***	0.129***	0.128***	0.092***	0.089***	0.089***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Log(Rainfall)	-0.010***		-0.010***	-0.010*		-0.010*	-0.010***		-0.010***
	(0.002)		(0.002)	(0.005)		(0.006)	(0.002)		(0.002)
L.Log(Rainfall)		0.001	0.005**		0.000	0.003		0.000	0.005**
		(0.002)	(0.002)		(0.005)	(0.006)		(0.002)	(0.002)
Observations	59,073	58,211	57,508	42,732	42,203	41,653	59,066	58,204	57,501
Municipalities	523	523	523	519	519	519	523	523	523

(b) Dependent variable: log(wages)

	Total			Agricultural			Nonagricultural		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year trend	0.023***	0.023***	0.022***	0.017***	0.017***	0.017***	0.024***	0.024***	0.023***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log(Rainfall)	-0.003***		-0.004***	-0.001		-0.000	-0.003***		-0.004***
	(0.001)		(0.001)	(0.001)		(0.001)	(0.001)		(0.001)
L.Log(Rainfall)		0.002*	0.003***		-0.002	-0.002		0.001	0.003***
		(0.001)	(0.001)		(0.001)	(0.001)		(0.001)	(0.001)
Observations	59,072	58,210	57,507	42,676	42,149	41,599	59,065	58,203	57,500
Municipalities	523	523	523	519	519	519	523	523	523

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 5: The effect of rain shocks in the formal rural labor market

(a) Dependent variable: log(employment)

	Total			Agricultural			Nonagricultural		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year trend	0.096***	0.093***	0.093***	0.128***	0.128***	0.128***	0.092***	0.089***	0.089***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
I [Precipitation] ≥ 80th percentile	-0.022***		-0.023***	-0.032***		-0.030***	-0.021***		-0.022***
	(0.005)		(0.005)	(0.011)		(0.011)	(0.005)		(0.005)
I [Precipitation] ≤ 20th percentile	0.021***		0.017***	0.020*		0.019	0.021***		0.017***
	(0.005)		(0.005)	(0.011)		(0.012)	(0.005)		(0.005)
L.I [Precipitation] ≥ 80th percentile		0.007	0.010**		-0.023**	-0.020*		0.008*	0.011**
		(0.005)	(0.005)		(0.011)	(0.011)		(0.005)	(0.005)
L.I [Precipitation] ≤ 20th percentile		0.009*	0.006		0.009	0.006		0.009*	0.006
		(0.005)	(0.005)		(0.012)	(0.012)		(0.005)	(0.005)
Observations	60,015	59,140	59,140	43,460	42,927	42,927	60,008	59,133	59,133
Municipalities	524	523	523	520	519	519	524	523	523

(b) Dependent variable: log(wages)

	Total			Agricultural			Nonagricultural		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year trend	0.023***	0.023***	0.022***	0.017***	0.017***	0.017***	0.024***	0.024***	0.024***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
I [Precipitation] ≥ 80th percentile	-0.012***		-0.012***	-0.001		-0.001	-0.013***		-0.013***
	(0.002)		(0.002)	(0.003)		(0.003)	(0.002)		(0.002)
I [Precipitation] ≤ 20th percentile	0.005**		0.005**	0.004		0.003	0.005**		0.004*
	(0.002)		(0.002)	(0.003)		(0.003)	(0.002)		(0.002)
L.I [Precipitation] ≥ 80th percentile		0.003	0.005**		-0.002	-0.002		0.002	0.004*
		(0.002)	(0.002)		(0.003)	(0.003)		(0.002)	(0.002)
L.I [Precipitation] ≤ 20th percentile		0.004**	0.003		-0.000	-0.001		0.004**	0.003
		(0.002)	(0.002)		(0.003)	(0.003)		(0.002)	(0.002)
Observations	60,014	59,139	59,139	43,404	42,871	42,871	60,007	59,132	59,132
Municipalities	524	523	523	520	519	519	524	523	523

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 6: The effects of El Niño and La Niña phenomena in the formal rural labor market

(a) Dependent variable: log(employment)

	Total								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year trend	0.097***	0.094***	0.093***	0.127***	0.126***	0.126***	0.092***	0.089***	0.089***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
I [La Niña=1]	0.001		-0.062***	-0.115***		-0.061***	0.012**		-0.060***
	(0.005)		(0.008)	(0.011)		(0.020)	(0.005)		(0.008)
I [El Niño=1]	0.004		-0.021**	-0.021*		0.011	0.010**		-0.020*
	(0.005)		(0.010)	(0.011)		(0.026)	(0.005)		(0.010)
L.I [La Niña=1]		0.009*	0.060***		-0.120***	-0.069***		0.020***	0.068***
		(0.005)	(0.008)		(0.011)	(0.020)		(0.005)	(0.008)
L.I [El Niño=1]		0.004	0.020*		-0.029**	-0.042*		0.010**	0.025**
		(0.005)	(0.010)		(0.011)	(0.025)		(0.005)	(0.010)
Observations	60,015	59,140	59,140	43,460	42,927	42,927	60,008	59,133	59,133
Municipalities	524	523	523	520	519	519	524	523	523

(b) Dependent variable: log(wages)

	Total								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year trend	0.023***	0.023***	0.022***	0.017***	0.017***	0.016***	0.024***	0.024***	0.024***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
I [La Niña=1]	-0.006***		-0.028***	-0.010***		-0.023***	-0.009***		-0.028***
	(0.002)		(0.004)	(0.003)		(0.005)	(0.002)		(0.004)
I [El Niño=1]	-0.010***		-0.003	0.001		0.006	-0.010***		-0.001
	(0.002)		(0.005)	(0.003)		(0.007)	(0.002)		(0.005)
L.I [La Niña=1]		-0.001	0.022***		-0.004	0.015***		-0.004**	0.019***
		(0.002)	(0.004)		(0.003)	(0.005)		(0.002)	(0.004)
L.I [El Niño=1]		-0.011***	-0.010**		0.002	-0.005		-0.011***	-0.012**
		(0.002)	(0.005)		(0.003)	(0.007)		(0.002)	(0.005)
Observations	60,014	59,139	59,139	43,404	42,871	42,871	60,007	59,132	59,132
Municipalities	524	523	523	520	519	519	524	523	523

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

In summary, the estimates from Tables 4 and 5 show that episodes of excessive rainfall during month t have an immediate effect on the rural formal labor market: Total employment decreases and wages principally fall for the non-agricultural sector. Thus, what we have named as excessive rain shocks are actually negative productivity shocks in rural areas. As stated by Jayachandran (2006), if "bad" weather conditions have implications on agricultural production, it also has consequences on the demand of labor and wages. If episodes with excessive rain are related with lower wages and employment in the formal rural labor market—as we have consistently found, are those results a sign of a negative productivity shock because laid off workers have to find a job either at the informal agricultural market or at the other economic sectors? That might be true if we could find an increase in informal jobs, which we suspect is the primary source for those affected with the weather shocks.

4.2 Addressing Heterogeneous Effects

The effects of rain shocks on formal employment and wages could not only vary by municipality, but also by type of crop. Based on information from the Colombian Agricultural Census of 2013 (hereafter CNA), we identify the most farmed crop on each municipality. According to the data, maize, potato, rice, yucca—as short-cycle crops, and coffee (late-blooming crop) are the crops with the largest extensions of farmed area in Colombia. Thus, we construct several subsamples that group municipalities by the most farmed crop, based on some thresholds (i.e., absolute terms, including only municipalities whose most farmed crop comprises 50 percent or more of total farmed land in the municipality, and those that are above the median of the distribution of the share of the corresponding crop on total farmed land by municipality). Figure 7 displays a Colombian map indicating the most relevant crop for the municipalities in our sample.

Tables 7 to 11 display the regression estimates of the effect of municipality-level rainfall shocks for those municipalities we identified as their most farmed crop (in absolute terms) one of the crops listed above. From the results, we observe that for maize-oriented municipalities the estimates are similar from those for the complete sample (Table 5), in terms of signs and statistical significance. More precisely, Table 9 shows that AA shocks decreases formal agricultural and non-agricultural employment by 7.9 and 2.9 percent, respectively, whereas BA shocks still have a positive effect on formal jobs in rural areas—6.4 and 3.1 percent in the agricultural and non-agricultural sectors, respectively. Lagged AA shocks are still negative (and statistically significant) for agricultural jobs, displaying the degree of persistence of this weather phenomenon in the very short term. Regarding wages, we find the effect of current and lagged AA shocks to be negative and statistically significant for the agricultural sector (-1.3 and -1.7 percent, respectively).

To a lesser extent, we can find similar results for potato-oriented municipalities, as displayed in Table 7. Here, we find negative effects of AA shocks on non-agricultural jobs, and positive impacts of current BA shocks on total employment as well. However, the results from Table 7 show that current and lagged episodes of AA shocks have a positive impact on agricultural jobs. Moreover, we do not find any statistically significant effect of wages for these municipalities. With respect to the remaining crops, we cannot find a consistent pattern of results that resemble our findings from Table 5.

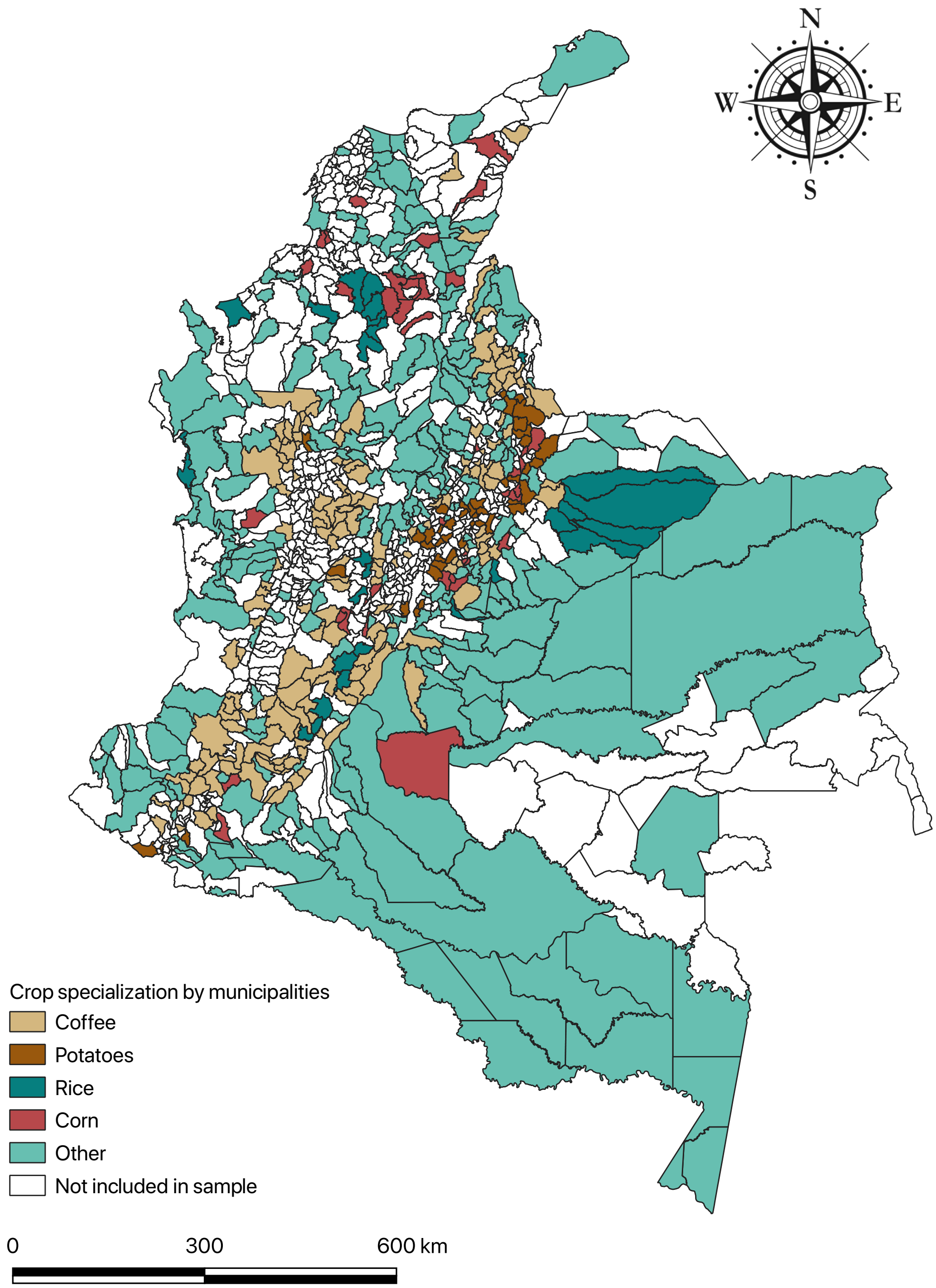


Figure 7: Map of municipalities by crop specialization

With respect to El Niño and La Niña phenomena, the regressions estimates from Tables 12 to 16 show that the effects on agricultural jobs and wages mostly take place in coffee, maize, and yucca-oriented municipalities, whereas the effects on the non-agricultural sector are located principally in coffee and potato-oriented municipalities. Comparing with the results from Tables 7 to 11, it seems that maize crops would be the most affected from rainfall shocks, either they are locally based or nationwide based. These results arise the question whether maize crops are less resilient to abrupt changes in precipitation in the short run due to high costs of adaptation (Kolstad and Moore, 2020).

Tables A1 to A20 from the Annex report the estimates regarding the effects of municipality-level rainfall shocks as well as El Niño and La Niña phenomena for those municipalities that have one of the crops of interest as the most farmed, but using two different thresholds for selection: municipalities whose most farmed crop embraces 50 percent or more of total farmed area, and those that the share of land of the most farmed crop is above the median of the distribution of those shares (e.g., if a potato-oriented municipality only devotes 20 percent of its farmed land to that crop, but the median value of the distribution of shares over all potato-oriented municipalities is greater than that value, we do not select that municipality). The results are less consistent than those from Tables 7 to 16, but they still show that municipalities where maize (and, to a lesser extent, potato) is the most farmed crop, the effects of rainfall shocks are significant.

Table 7: The effect of weather shocks on potato-oriented municipalities (most farmed crop by municipality in absolute terms)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.046***	0.124***	0.044***	0.012***	0.013***	0.014***
	(0.002)	(0.005)	(0.002)	(0.001)	(0.001)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.032***	0.034	-0.033***	-0.006	0.002	-0.006
	(0.012)	(0.041)	(0.012)	(0.007)	(0.008)	(0.007)
I [Precipitation] $\leq$ 20th percentile	0.031**	0.076*	0.030**	0.007	-0.004	0.009
	(0.012)	(0.040)	(0.012)	(0.007)	(0.008)	(0.007)
L.I [Precipitation] $\geq$ 80th percentile	0.025**	0.004	0.029**	0.005	0.008	0.005
	(0.012)	(0.040)	(0.012)	(0.007)	(0.008)	(0.007)
L.I [Precipitation] $\leq$ 20th percentile	0.010	0.082**	0.009	0.006	-0.012	0.008
	(0.012)	(0.040)	(0.012)	(0.007)	(0.008)	(0.007)
Observations	4,849	4,849	4,849	4,849	3,455	4,849
Municipalities	44	44	44	44	44	44

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 8: The effect of weather shocks on rice-oriented municipalities (most farmed crop bymunicipality in absolute terms)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.095***	0.211***	0.083***	0.024***	0.020***	0.024***
	(0.002)	(0.005)	(0.002)	(0.001)	(0.002)	(0.001)
I [Precipitation] $\geq$ 80th percentile	0.008	-0.004	0.007	-0.000	0.014	-0.003
	(0.015)	(0.038)	(0.015)	(0.007)	(0.011)	(0.007)
I [Precipitation] $\leq$ 20th percentile	0.042***	0.087**	0.036**	0.014**	-0.009	0.011
	(0.015)	(0.041)	(0.016)	(0.007)	(0.012)	(0.007)
L.I [Precipitation] $\geq$ 80th percentile	-0.006	-0.009	-0.009	0.002	0.007	0.000
	(0.014)	(0.038)	(0.015)	(0.007)	(0.011)	(0.007)
L.I [Precipitation] $\leq$ 20th percentile	-0.008	0.061	-0.006	-0.009	-0.016	-0.010
	(0.015)	(0.041)	(0.016)	(0.007)	(0.012)	(0.007)
Observations	4,232	4,232	4,232	4,232	4,008	4,232
Municipalities	36	36	36	36	36	36

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 9: The effect of weather shocks on maize-oriented municipalities (most farmed crop by municipality in absolute terms)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.088***	0.144***	0.083***	0.020***	0.015***	0.022***
	(0.001)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.031***	-0.079***	-0.029***	-0.013**	-0.013*	-0.013**
	(0.011)	(0.025)	(0.011)	(0.005)	(0.007)	(0.005)
I [Precipitation] $\leq$ 20th percentile	0.032***	0.064**	0.031***	0.003	0.004	0.004
	(0.011)	(0.026)	(0.011)	(0.006)	(0.007)	(0.006)
L.I [Precipitation] $\geq$ 80th percentile	0.007	-0.094***	0.010	0.005	-0.017**	0.006
	(0.011)	(0.025)	(0.011)	(0.005)	(0.007)	(0.005)
L.I [Precipitation] $\leq$ 20th percentile	0.001	0.037	-0.001	-0.012**	0.007	-0.012**
	(0.011)	(0.026)	(0.011)	(0.006)	(0.007)	(0.006)
Observations	10,853	10,853	10,853	10,853	6,975	10,853
Municipalities	96	96	96	96	94	96

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 10: The effect of weather shocks on yucca-oriented municipalities (most farmed crop by municipality in absolute terms)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.143***	0.194***	0.138***	0.035***	-0.001	0.037***
	(0.003)	(0.006)	(0.003)	(0.001)	(0.002)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.060***	0.001	-0.060***	-0.038***	-0.000	-0.040***
	(0.019)	(0.041)	(0.019)	(0.007)	(0.013)	(0.007)
I [Precipitation] $\leq$ 20th percentile	0.004	0.058	-0.000	-0.012*	0.026**	-0.015**
	(0.020)	(0.042)	(0.019)	(0.007)	(0.013)	(0.007)
L.I [Precipitation] $\geq$ 80th percentile	0.014	-0.054	0.019	0.004	0.018	0.003
	(0.019)	(0.041)	(0.019)	(0.007)	(0.013)	(0.007)
L.I [Precipitation] $\leq$ 20th percentile	-0.005	0.045	-0.012	-0.002	0.033**	-0.002
	(0.020)	(0.043)	(0.020)	(0.007)	(0.013)	(0.007)
Observations	5,618	5,618	5,618	5,612	3,637	5,612
Municipalities	49	49	49	49	49	49

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 11: The effect of weather shocks on coffee-oriented municipalities (most farmed crop by municipality in absolute terms)

	Employment			Wages		
	(1)	(2)	(3)	(4)	(5)	(6)
	Total	Agricultural	Nonagricultural	Total	Agricultural	Nonagricultural
Year trend	0.089***	0.213***	0.084***	0.021***	0.022***	0.022***
	(0.001)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.025***	-0.012	-0.024***	-0.014***	0.002	-0.015***
	(0.009)	(0.026)	(0.009)	(0.004)	(0.006)	(0.004)
I [Precipitation] $\leq$ 20th percentile	0.003	-0.015	0.005	0.006	0.001	0.004
	(0.009)	(0.026)	(0.009)	(0.004)	(0.006)	(0.004)
L.I [Precipitation] $\geq$ 80th percentile	-0.009	0.008	-0.011	-0.002	0.004	-0.003
	(0.009)	(0.026)	(0.009)	(0.004)	(0.006)	(0.004)
L.I [Precipitation] $\leq$ 20th percentile	0.023***	0.013	0.023***	0.019***	-0.001	0.019***
	(0.009)	(0.026)	(0.009)	(0.004)	(0.006)	(0.004)
Observations	11,666	11,666	11,666	11,666	8,396	11,666
Municipalities	104	104	104	104	103	104

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 12: The effects of El Niño and La Niña phenomena on potato-oriented municipalities (most farmed crop by municipality in absolute terms)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.047***	0.122***	0.045***	0.013***	0.013***	0.014***
	(0.002)	(0.006)	(0.002)	(0.001)	(0.001)	(0.001)
I [La Niña=1]	-0.093***	0.019	-0.096***	-0.037***	-0.005	-0.035***
	(0.021)	(0.070)	(0.021)	(0.012)	(0.014)	(0.012)
I [El Niño=1]	-0.039	0.001	-0.041	0.016	-0.005	0.019
	(0.027)	(0.089)	(0.027)	(0.015)	(0.018)	(0.015)
L.I [La Niña=1]	0.121***	-0.064	0.128***	0.048***	0.017	0.047***
	(0.021)	(0.070)	(0.021)	(0.012)	(0.014)	(0.012)
L.I [El Niño=1]	0.065**	0.144	0.065**	0.008	-0.008	0.009
	(0.027)	(0.088)	(0.027)	(0.015)	(0.018)	(0.015)
Observations	4,849	4,849	4,849	4,849	3,455	4,849
Municipalities	44	44	44	44	44	44

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 13: The effects of El Niño and La Niña phenomena on rice-oriented municipalities (most farmed crop by municipality in absolute terms)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.095***	0.208***	0.084***	0.024***	0.020***	0.023***
	(0.002)	(0.005)	(0.002)	(0.001)	(0.002)	(0.001)
I [La Niña=1]	-0.023	-0.000	-0.011	-0.033***	-0.019	-0.029**
	(0.026)	(0.069)	(0.027)	(0.012)	(0.020)	(0.012)
I [El Niño=1]	0.007	-0.136	0.027	-0.010	-0.047*	0.000
	(0.033)	(0.087)	(0.034)	(0.015)	(0.025)	(0.015)
L.I [La Niña=1]	0.023	-0.185***	0.026	0.017	0.047**	0.003
	(0.026)	(0.069)	(0.027)	(0.012)	(0.020)	(0.012)
L.I [El Niño=1]	-0.016	0.063	-0.018	-0.025*	0.024	-0.031**
	(0.033)	(0.087)	(0.034)	(0.015)	(0.025)	(0.015)
Observations	4,232	4,232	4,232	4,232	4,008	4,232
Municipalities	36	36	36	36	36	36

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 14: The effects of El Niño and La Niña phenomena on maize-oriented municipalities (most farmed crop by municipality in absolute terms)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.088***	0.140***	0.084***	0.020***	0.015***	0.022***
	(0.001)	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)
I [La Niña=1]	-0.101***	-0.106**	-0.096***	-0.028***	-0.026**	-0.030***
	(0.019)	(0.044)	(0.019)	(0.009)	(0.012)	(0.010)
I [El Niño=1]	-0.004	0.059	-0.005	-0.009	0.010	-0.009
	(0.024)	(0.056)	(0.024)	(0.012)	(0.015)	(0.012)
L.I [La Niña=1]	0.089***	-0.179***	0.099***	0.036***	-0.008	0.033***
	(0.019)	(0.044)	(0.019)	(0.009)	(0.012)	(0.010)
L.I [El Niño=1]	-0.007	-0.118**	0.001	0.002	-0.014	0.001
	(0.024)	(0.056)	(0.024)	(0.012)	(0.015)	(0.012)
Observations	10,853	10,853	10,853	10,853	6,975	10,853
Municipalities	96	96	96	96	94	96

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 15: The effects of El Niño and La Niña phenomena on yucca-oriented municipalities (most farmed crop by municipality in absolute terms)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.142***	0.190***	0.137***	0.034***	-0.001	0.036***
	(0.003)	(0.006)	(0.003)	(0.001)	(0.002)	(0.001)
I [La Niña=1]	-0.068**	-0.029	-0.071**	-0.044***	-0.054**	-0.043***
	(0.033)	(0.071)	(0.033)	(0.012)	(0.022)	(0.012)
I [El Niño=1]	-0.109**	0.067	-0.126***	-0.013	0.060**	-0.013
	(0.042)	(0.092)	(0.042)	(0.016)	(0.029)	(0.016)
L.I [La Niña=1]	0.010	-0.208***	0.017	0.014	0.021	0.011
	(0.033)	(0.071)	(0.033)	(0.012)	(0.022)	(0.012)
L.I [El Niño=1]	0.027	-0.110	0.025	-0.029*	-0.012	-0.032**
	(0.042)	(0.091)	(0.042)	(0.016)	(0.029)	(0.016)
Observations	5,618	5,618	5,618	5,612	3,637	5,612
Municipalities	49	49	49	49	49	49

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 16: The effects of El Niño and La Niña phenomena on coffee-oriented municipalities (most farmed crop by municipality in absolute terms)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.089***	0.207***	0.085***	0.021***	0.022***	0.022***
	(0.001)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
I [La Niña=1]	-0.045***	-0.065	-0.042***	-0.012	-0.025**	-0.010
	(0.015)	(0.045)	(0.015)	(0.008)	(0.010)	(0.008)
I [El Niño=1]	-0.004	-0.047	0.000	-0.004	0.019	-0.004
	(0.019)	(0.057)	(0.020)	(0.010)	(0.013)	(0.010)
L.I [La Niña=1]	0.048***	-0.141***	0.055***	0.006	0.026**	0.003
	(0.015)	(0.045)	(0.015)	(0.008)	(0.010)	(0.008)
L.I [El Niño=1]	0.031	0.001	0.034*	-0.006	-0.005	-0.007
	(0.019)	(0.057)	(0.019)	(0.010)	(0.013)	(0.010)
Observations	11,666	11,666	11,666	11,666	8,396	11,666
Municipalities	104	104	104	104	103	104

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

The existence of irrigation systems can help farms to mitigate the effects of episode of little rain or droughts. Again, using information from the 2013 CNA, we identify whether an agricultural production unit (UPA in Spanish) has irrigation used for agricultural production. Then, we calculate the share of UPA with irrigation by municipality. A given municipality is categorized as with low incidence of irrigation systems whether that share is less than 50 percent of total UPA. Otherwise, they are cataloged as with high incidence.

Tables 17 and 18 display the regression estimates of Equation 2 for the sub-samples of municipalities classified according to the incidence of irrigation systems. Regarding the effect of municipality-level rainfall episodes, we find that current AA shocks have a negative effect on total employment and average earnings on those municipalities with low share of UPA with irrigation. Likewise, such that effect is negative for high-incidence municipalities, but the estimated coefficient is smaller on employment (-0.028 Vs. -0.016). Nevertheless, we do not find a statistically significant effect of these shocks on agricultural employment and wages on those municipalities with a high share of UPA with irrigation. This results will lead us to consider that farms with irrigation systems could also count with drains that help them to mitigate the effects of excessive rainfall. However, we do count with data that help us to corroborate this hypothesis. Past realizations of AA shocks still have a negative effect of agricultural employment on low-incidence municipalities.

On the other hand, we find a positive impact of current BA shocks on agricultural employment on high-incidence municipalities. That is, farms with irrigation systems hire more employment that their counterparts during episodes of little rainfall. This finding could be the results of these farms having the advantage of continuing their production—even to increase it, so they can hire additional labor. Nevertheless, we do not find any statistically significant effect on wages.

With respect to El Niño and La Niña phenomena, the results come with some surprise. First, we do not find any statistically significant effect of current realizations of these events on agricultural employment for municipalities with low incidence of irrigation systems. However, past episodes of La Niña have a negative impact on agricultural employment for this category of municipalities, and the effect is positive for non-agricultural employment and wages. Regarding El Niño, non-agricultural employment for these municipalities is affected by that event, but the recovery seems to be fast, due to the positive sign of the coefficient associated with lagged episodes. For municipalities with high incidence of irrigation, current realizations of La Niña have a negative impact on total employment. But employment in these municipalities is not affected by El Niño, and we only observe a fall in wages for the non-agricultural sector due to lagged episodes.

Table 17: The effect of rain shocks in the formal rural labor market (controlling by the incidence of irrigation systems)

(a) Dependent variable: log(employment)

	Low use of irrigation			High use of irrigation		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.096***	0.184***	0.092***	0.093***	0.153***	0.088***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.028***	-0.036**	-0.027***	-0.016**	-0.013	-0.015**
	(0.007)	(0.017)	(0.007)	(0.006)	(0.015)	(0.006)
I [Precipitation] $\leq$ 20th percentile	0.007	0.007	0.008	0.025***	0.043***	0.023***
	(0.007)	(0.018)	(0.007)	(0.006)	(0.015)	(0.006)
L.I [Precipitation] $\geq$ 80th percentile	-0.001	-0.047***	0.001	0.021***	-0.020	0.022***
	(0.007)	(0.017)	(0.007)	(0.006)	(0.015)	(0.006)
L.I [Precipitation] $\leq$ 20th percentile	0.003	0.019	0.002	0.009	0.012	0.009
	(0.007)	(0.018)	(0.007)	(0.006)	(0.015)	(0.006)
Observations	27,864	27,864	27,864	31,381	31,381	31,381
Municipalities	247	247	247	276	276	276

(b) Dependent variable: log(wages)

	Low use of irrigation			High use of irrigation		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.020***	0.017***	0.021***	0.025***	0.017***	0.026***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
I [Precipitation] $\geq$ 80th percentile	-0.011***	-0.005	-0.011***	-0.013***	0.003	-0.015***
	(0.003)	(0.005)	(0.003)	(0.003)	(0.004)	(0.003)
I [Precipitation] $\leq$ 20th percentile	0.003	0.006	0.002	0.006**	0.001	0.006**
	(0.003)	(0.005)	(0.003)	(0.003)	(0.004)	(0.003)
L.I [Precipitation] $\geq$ 80th percentile	0.003	-0.003	0.003	0.006**	-0.001	0.005
	(0.003)	(0.005)	(0.003)	(0.003)	(0.004)	(0.003)
L.I [Precipitation] $\leq$ 20th percentile	0.008***	0.003	0.008***	-0.000	-0.004	-0.000
	(0.003)	(0.005)	(0.003)	(0.003)	(0.004)	(0.003)
Observations	27,800	19,322	27,795	31,339	23,549	31,337
Municipalities	247	244	247	276	275	276

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table 18: The effects of El Niño and La Niña phenomena in the formal rural labor market (controlling by the incidence of irrigation systems)

(a) Dependent variable: log(employment)

	Low use of irrigation			High use of irrigation		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.096***	0.180***	0.092***	0.093***	0.149***	0.089***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
I [La Niña=1]	-0.058***	-0.038	-0.056***	-0.063***	-0.075***	-0.060***
	(0.012)	(0.030)	(0.012)	(0.011)	(0.026)	(0.011)
I [El Niño=1]	-0.040**	0.003	-0.038**	-0.005	0.002	-0.005
	(0.016)	(0.038)	(0.016)	(0.014)	(0.033)	(0.014)
L.I [La Niña=1]	0.041***	-0.165***	0.049***	0.073***	-0.117***	0.083***
	(0.012)	(0.030)	(0.012)	(0.011)	(0.026)	(0.011)
L.I [El Niño=1]	0.049***	-0.045	0.054***	0.001	-0.041	0.007
	(0.016)	(0.038)	(0.016)	(0.014)	(0.033)	(0.014)
Observations	27,864	27,864	27,864	31,381	31,381	31,381
Municipalities	247	247	247	276	276	276

(b) Dependent variable: log(wages)

	Low use of irrigation			High use of irrigation		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.020***	0.016***	0.021***	0.025***	0.017***	0.026***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
I [La Niña=1]	-0.026***	-0.032***	-0.024***	-0.029***	-0.015**	-0.030***
	(0.005)	(0.008)	(0.005)	(0.005)	(0.006)	(0.005)
I [El Niño=1]	-0.007	0.017	-0.006	0.001	-0.004	0.004
	(0.006)	(0.011)	(0.006)	(0.007)	(0.008)	(0.007)
L.I [La Niña=1]	0.021***	0.013	0.018***	0.023***	0.016***	0.019***
	(0.005)	(0.008)	(0.005)	(0.005)	(0.006)	(0.005)
L.I [El Niño=1]	0.000	-0.008	-0.001	-0.019***	-0.001	-0.021***
	(0.006)	(0.011)	(0.006)	(0.007)	(0.008)	(0.007)
Observations	27,800	19,322	27,795	31,339	23,549	31,337
Municipalities	247	244	247	276	275	276

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

4.3 The Effects on the Formal Labor Market using GEIH

As the PILA does not have information on individuals who are on other labor market states besides formal employment, we also use data from the GEIH household survey that allows us to observe individuals who work informally, individuals who are unemployed individuals and those who are out of the labor force (OLF). Although this allows us to specifically study what happens with informality, our specification when using these data changes because the GEIH is not a panel at the individual level and it does not allow us to follow municipalities in time as the municipalities included each month vary because of the sampling methodology used in the survey. Therefore, we switch to an individual level model to estimate the likelihood of individuals being formal or being in any other labor market state. We do so by using pooled data, controling for demographic characteristics, a year trend and municipality and month fixed effects.

Our general specification is the following:

$$Y_{jim} = \beta_0 + \beta_1 W^+_{im} + \beta_2 W^-_{im} + \beta_3 W^+_{i,m-1} + \beta_4 W^-_{i,m-1} + X\gamma + \delta T + a_i + b_m + u_{j,i,m} \qquad (2)$$

where Y_{jim} is a dichotomous outcome of interest for individual j, located in municipality i at month m, $W^+_{i,m}$, $W^+_{i,m-1}$, $W^-_{i,m}$, and $W^-_{i,m-1}$ account for current and lagged realizations of our measures of rainfall of interest, respectively. [7] X is a matrix with individual socio-demographic characteristics (sex, age, if the individual is the head of the household, marital status, schooling), T is a yearly linear trend that accounts for the passage of time; a_i and b_m are the municipality and month fixed effects, respectively, and u_{jim} is a zero-mean error.

[7] The inclusion of past realizations of precipitation events intend to account for the persistence of those episodes on current employment.

From this model, the parameters of interest are β_1 to β_4, since they intend to capture the effect of current and past weather shocks on changes in formal unemployment or wages from their averages.

The results from Tables 19 and 20 show that excess rain shocks has a negative effect of 0.4% on the likelihood of being formal, suggesting that individuals stay in unemployment or out of the labor force when there are excess rain shocks. On the other hand, Table 21 shows that current excess rain shocks have a small positive effect on the likelihood of working informally when compared to being unemployed or out of the labor force, but lagged rain shocks are highly significant and both types of shocks (excess rain or lack of rain) in the previous period increase the likelihood of being unemployed or out of the labor force in the current period.

Table 19: The effect of rain shocks on the likelihood of working formally vs. being unemployed or OLF

Dep. var: =1 if works informally, =0 if formal, unemployed or OLF

	(1) (s.e.)	(2) (s.e.)	(3) (s.e.)	(4) (s.e.)
Year Trend	0.004**	0.004**	0.001**	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
[$\geq$ 80th perc.]	- 0.002**	- 0.002**	- 0.002**	- 0.002**
	(0.001)	(0.001)	(0.001)	(0.001)
[$\leq$ 20th perc.]	0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)
L.[$\geq$ 80th perc.]		-0.001		-0.000
		(0.001)		(0.001)
L.[$\leq$ 20th perc.]		-0.001		0.000
		(0.001)		(0.001)
Controls	No	No	Yes	Yes
N	534.015	528.129	534.015	528.129

Notes: Dependent variable: Dummy variable equals to 1 if individual works informally, equals to 0 if individual is unemployed or is out of the labor force (OLF). Robust standard errors in parentheses. Significance: $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. This table shows pooled OLS results. Controls included in columns (2) and (4) are dummy for sex, age, schooling, if the individual is head of the household and marital status. Month and municipality fixed effects are included in columns (3) and (4).

Table 20: The effect of rain shocks on the likelihood of working formally vs. being unemployed or OLF

Dep. var,: =1 if works formally, =0 if unemployed or OLF

	(1) (s.e.)	(2) (s.e.)	(3) (s.e.)	(4) (s.e.)
Year Trend	0.007**	0.007**	0.002**	0.002**
	(0.000)	(0.000)	(0.000)	(0.000)
[≥ 80th perc.]	-0.004**	-0.004**	-0.003**	-0.003**
	(0.002)	(0.002)	(0.001)	(0.001)
[≤ 20th perc.]	0.001	0.001	-0.000	-0.000
	(0.002)	(0.002)	(0.001)	(0.001)
L.[≥ 80th perc.]		-0.002		-0.002
		(0.001)		(0.001)
L.[≤ 20th perc.]		-0.003*		-0.002
		(0.002)		(0.001)
Controls	No	No	Yes	Yes
N	279.820	276.595	279.820	276.595

Notes: Dependent variable: Dummy variable equals to 1 if individual works informally, equals to 0 if individual is unemployed or is out of the labor force (OLF). Robust standard errors in parentheses. Significance: $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. This table shows pooled OLS results. Controls included in columns (2) and (4) are dummy for sex, age, schooling, if the individual is head of the household and marital status. Month and municipality fixed effects are included in columns (3) and (4).

Table 21: The effect of rain shocks on the likelihood of working informally vs. being unemployed or OLF

Dependent variable: =1 if works informally, =0 if unemployed or OLF

	(1) (s.e.)	(2) (s.e.)	(3) (s.e.)	(4) (s.e.)
Year Trend	0.003**	0.003**	0.004**	0.004**
	(0.000)	(0.000)	(0.000)	(0.000)
[≥ 80th perc.]	0.002*	0.002*	0.002*	0.002*
	(0.001)	(0.001)	(0.001)	(0.001)
[≤ 20th perc.]	-0.001	-0.000	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
L.[≥ 80th perc.]		-0.003**		-0.003**
		(0.001)		(0.001)
L.[≤ 20th perc.]		-0.004***		-0.004***
		(0.001)		(0.001)
Controls	No	No	Yes	Yes
N	273.398	270.493	273.398	270.493

Notes: Dependent variable: Dummy variable equals to 1 if individual works informally, equals to 0 if individual is unemployed or is out of the labor force (OLF). Robust standard errors in parentheses. Significance: $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. This table shows pooled OLS results. Controls included in columns (2) and (4) are dummy for sex, age, schooling, if the individual is head of the household and marital status. Month and municipality fixed effects are included in columns (3) and (4).

5 Discussion and Further Steps

We find that episodes of monthly rainfall above the 80th percentile of its historical distribution have a negative effect on rural formal employment for both the non-agricultural and agricultural sectors that ranges between -2.2 and -3 percent, respectively. Regarding earnings, the effect of excessive rainfall lies between -1.2 and -1.3 percent for the agricultural non-agricultural sectors, respectively. Likewise, we find that both El Niño and La Niña phenomena have a negative effect on total formal employment in rural areas. Moreover, the overall impact of La Niña is larger than El Niño. Furthermore, these shocks present some degree of persistence, at least at the very short term. Our estimates differ from those found for Southeast Asia and India, in which excessive rainfall episodes (e.g., monsoon periods) are positive shocks for agricultural production. Thus, we argue that such differences could be due to the heterogeneity of geographic, orographic, and pluviometric conditions across countries, which have an incidence in the way that precipitation affects agriculture.

Additionally, we explore if the effect of rain shocks varies depending on the access to irrigation and drainage technologies. Results indicate that municipalities with high prevalence of irrigation systems are less affected by episodes of low rainfall. We also study if there are heterogenous effects depending on the crop type by focusing on five popular crops (maize, yucca, rice, coffee and potato), only finding effects on the municipalities in which maize and potato are the most farmed crops. We argue this could happen given that both crops are very artisan in Colombia.

When looking at the individual level decision of working formally or being informal, unemployed, or out of the labor force, we find that excess rain shocks also have a negative effect on the likelihood of working formally with respect to all the other possible labor market states, including working informally. On the other hand, if we only take into account the margin of informality versus unemployment and inactivity, the results show that positive rain shocks may slightly increase the likelihood of working informally, but both lagged shocks of rain above the 80th percentile and below the 20th percentile have a negative effect on informal employment. This suggests that there may be a transition of formal workers to all the other labor market states when there are episodes of monthly rainfall above the 80th percentile of its historical distribution.

Although we are still working on addressing the mechanisms through which these effects are happening, such as the role that migration and the access to credit have on labor markets in rural areas, our results from PILA and GEIH, combined, show that excess rain acts as a negative productivity shock as formal employment is destroyed.Policies aimed to promote formalization in the labor market should take into consideration such phenomenon as excess rain shocks are more common nowadays than before.

References

Adhvaryu, A., A.V. Chari, and S. Sharma. 2013. “Firing costs and flexibility: evidence from firms’ employment responses to shocks in India.” *Review of Economics and Statistics* 95:725–740.

Almeida, R., and P. Carneiro. 2012. “Enforcement of labor regulation and informality.” *American Economic Journal: Applied Economics* 4:64–89.

Bobba, M., L. Flabbi, and S. Levy. 2018. “Labor market search, informality and schooling investments.”, pp. .

Brey, B., and M.S. Hertweck. 2019. “Agricultural productivity shocks and poverty in India: The short-and long-term effects of monsoon rainfall.”, pp. .

Burzyński, M., C. Deuster, F. Docquier, and J. De Melo. 2019. “Climate Change, Inequality, and Human Migration.”, pp. .

Calderón-Mejia, V., and A.M. Ibáñez. 2016. “Labour market effects of migration-related supply shocks: evidence from internal refugees in Colombia.” *Journal of Economic Geography* 16:695–713.

Chaurey, R. 2015. “Labor regulations and contract labor use: Evidence from Indian firms.” *Journal of Development Economics* 114:224–232.

Dillon, A., V. Mueller, and S. Salau. 2011. “Migratory responses to agricultural risk in northern Nigeria.” *American Journal of Agricultural Economics* 93:1048–1061.

Fernández, M., A.M. Ibáñez, and X. Peña. 2014. “Adjusting the Labour Supply to Mitigate Violent Shocks: Evidence from Rural Colombia.” *The Journal of Development Studies* 50:1135–1155.

Jayachandran, S. 2006. "Selling labor low: Wage responses to productivity shocks in developing countries." *Journal of political Economy* 114:538–575.

Jessoe, K., D.T. Manning, and J.E. Taylor. 2018. "Climate Change and Labour Allocation in Rural Mexico: Evidence from Annual Fluctuations in Weather." *Economic Journal* 128:230–261.

Kochar, A. 1999. "Smoothing Consumption by Smoothing Income: Hours-of-Work Responses to Idiosyncratic Agricultural Shocks in Rural India." *The Review of Economics and Statistics* 81:50–61.

Kolstad, C.D., and F.C. Moore. 2020. "Estimating the economic impacts of climate change using weather observations." *Review of Environmental Economics and Policy* 14:1–24.

Leibovich, J., M. Nigrinis-Ospina, M.A. Ramos-Veloza, and M.A. Ramos-Veloza. 2006. "Caracterización del mercado laboral rural en Colombia." Working paper No. 408.

Loayza, N.V., E. Olaberria, J. Rigolini, and L. Christiaensen. 2012. "Natural disasters and growth: Going beyond the averages." *World Development* 40:1317–1336.

Maitra, P., and A. Tagat. 2019. "Labour Supply Responses to Rainfall Shocks." Working paper.

Meghir, C., R. Narita, and J.M. Robin. 2015. "Wages and informality in developing countries." *American Economic Review* 105:1509–46.

Merchán, C.A., et al. 2015. "Sector rural colombiano: dinámica laboral y opciones de afiliación a la seguridad social." Unpublished.

Mueller, V.A., and D.E. Osgood. 2009. "Long-term impacts of droughts on labour markets in developing countries: Evidence from Brazil." *The Journal of Development Studies* 45:1651–1662.

Otero-Cortés, A. 2019. "El mercado laboral rural en Colombia, 2010-2019."

Pratap, S., and E. Quintin. 2006. "Are labor markets segmented in developing countries? A semiparametric approach." *European Economic Review* 50:1817–1841.

Quinones, E.J. 2018. "Anticipatory Migration and Local Labor Responses to Rural Climate Shocks." Unpublished.

Sanchez-Jabba, A.S., et al. 2014. *Análisis de la respuesta del Estado colombiano frente al Fenómeno de La Niña 2010-2011: El caso de Santa Lucía*. CEER.

Tannuri-Pianto, M., D. Pianto, O. Arias, et al. 2004. "Informal Employment in Bolivia: A lost proposition?" *World Bank, mimeo*, pp. .

Ulyssea, G. 2020. "Informality: Causes and Consequences for Development." *Annual Review of Economics* 12.

Ulyssea, G., and V. Ponczek. 2018. "Enforcement of Labor Regulation and the Labor Market Effects of Trade: Evidence from Brazil." IZA Discussion Papers No. 11783, Institute of Labor Economics (IZA), Aug.

A.1 Regression estimates by crops, including only municipalities above 50 percent of total farmed land

Table A1: The effect of weather shocks on potato-oriented municipalities (most farmed crop by municipality, above 50 percent of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.034***	0.070***	0.033***	0.009***	0.018***	0.009***
	(0.002)	(0.007)	(0.002)	(0.001)	(0.001)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.007	0.026	-0.007	-0.009	-0.003	-0.008
	(0.017)	(0.055)	(0.017)	(0.010)	(0.009)	(0.010)
I [Precipitation] $\leq$ 20th percentile	0.041**	0.061	0.041**	0.011	0.006	0.013
	(0.017)	(0.055)	(0.017)	(0.010)	(0.008)	(0.010)
L.I [Precipitation] $\geq$ 80th percentile	0.049***	-0.019	0.053***	0.003	0.006	0.002
	(0.017)	(0.055)	(0.017)	(0.010)	(0.009)	(0.010)
L.I [Precipitation] $\leq$ 20th percentile	0.002	0.063	0.002	0.004	0.003	0.005
	(0.017)	(0.055)	(0.017)	(0.010)	(0.008)	(0.010)
Observations	2,375	2,375	2,375	2,375	1,828	2,375
Municipalities	22	22	22	22	22	22

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A2: The effect of weather shocks on rice-oriented municipalities most farmed crop by municipality, above 50 percent of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.089***	0.237***	0.075***	0.024***	0.022***	0.023***
	(0.003)	(0.010)	(0.003)	(0.001)	(0.002)	(0.001)
I [Precipitation] $\geq$ 80th percentile	0.013	0.077	0.001	-0.006	0.013	-0.013
	(0.023)	(0.067)	(0.024)	(0.010)	(0.015)	(0.010)
I [Precipitation] $\leq$ 20th percentile	0.065***	0.077	0.055**	0.015	0.001	0.009
	(0.025)	(0.074)	(0.027)	(0.011)	(0.017)	(0.011)
L.I [Precipitation] $\geq$ 80th percentile	-0.022	0.032	-0.028	-0.005	-0.005	-0.008
	(0.023)	(0.067)	(0.024)	(0.010)	(0.015)	(0.010)
L.I [Precipitation] $\leq$ 20th percentile	0.013	0.061	0.014	-0.010	-0.025	-0.011
	(0.025)	(0.074)	(0.027)	(0.011)	(0.017)	(0.011)
Observations	1,859	1,859	1,859	1,859	1,702	1,859
Municipalities	16	16	16	16	16	16

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A3: The effect of weather shocks on maize-oriented municipalities (most farmed crop by municipality, above 50 percent of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.076***	0.101***	0.071***	0.021***	0.026***	0.023***
	(0.002)	(0.007)	(0.003)	(0.001)	(0.002)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.054***	-0.134***	-0.050***	-0.026**	-0.009	-0.028***
	(0.018)	(0.049)	(0.018)	(0.010)	(0.012)	(0.010)
I [Precipitation] $\leq$ 20th percentile	0.020	0.158***	0.013	-0.009	0.008	-0.009
	(0.019)	(0.051)	(0.019)	(0.011)	(0.012)	(0.011)
L.I [Precipitation] $\geq$ 80th percentile	0.023	-0.107**	0.023	0.011	-0.028**	0.011
	(0.018)	(0.049)	(0.018)	(0.010)	(0.012)	(0.010)
L.I [Precipitation] $\leq$ 20th percentile	-0.006	0.085*	-0.010	-0.018*	0.018	-0.020*
	(0.019)	(0.051)	(0.019)	(0.011)	(0.012)	(0.011)
Observations	2,673	2,673	2,673	2,673	1,944	2,673
Municipalities	24	24	24	24	22	24

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A4: The effect of weather shocks on yucca-oriented municipalities (most farmed crop by municipality, above 50 percent of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.185***	0.067***	0.197***	0.060***	0.039***	0.059***
	(0.008)	(0.021)	(0.007)	(0.003)	(0.006)	(0.003)
I [Precipitation] $\geq$ 80th percentile	-0.094*	-0.022	-0.095*	-0.073***	-0.001	-0.073***
	(0.055)	(0.153)	(0.054)	(0.020)	(0.043)	(0.019)
I [Precipitation] $\leq$ 20th percentile	-0.021	0.003	-0.017	-0.017	0.076*	-0.028
	(0.062)	(0.175)	(0.062)	(0.023)	(0.043)	(0.022)
L.I [Precipitation] $\geq$ 80th percentile	0.040	-0.135	0.057	0.028	0.053	0.019
	(0.055)	(0.153)	(0.054)	(0.020)	(0.044)	(0.019)
L.I [Precipitation] $\leq$ 20th percentile	-0.048	-0.079	-0.049	0.006	0.108**	-0.001
	(0.063)	(0.176)	(0.062)	(0.023)	(0.043)	(0.022)
Observations	703	703	703	703	388	703
Municipalities	6	6	6	6	6	6

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A5: The effect of weather shocks on coffee-oriented municipalities most farmed crop by municipality, above 50 percent of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.091***	0.191***	0.087***	0.027***	0.017***	0.027***
	(0.002)	(0.007)	(0.002)	(0.001)	(0.001)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.028*	-0.029	-0.030*	-0.003	0.005	-0.005
	(0.017)	(0.048)	(0.017)	(0.008)	(0.010)	(0.008)
I [Precipitation] $\leq$ 20th percentile	-0.000	-0.036	0.003	0.012	-0.007	0.010
	(0.017)	(0.048)	(0.017)	(0.008)	(0.010)	(0.008)
L.I [Precipitation] $\geq$ 80th percentile	-0.034**	-0.031	-0.037**	-0.012	0.004	-0.012
	(0.016)	(0.048)	(0.017)	(0.008)	(0.010)	(0.008)
L.I [Precipitation] $\leq$ 20th percentile	0.020	0.058	0.015	0.007	0.006	0.010
	(0.017)	(0.048)	(0.017)	(0.008)	(0.010)	(0.008)
Observations	3,979	3,979	3,979	3,979	2,749	3,979
Municipalities	35	35	35	35	35	35

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A6: The effects of El Niño and La Niña phenomena on potato-oriented municipalities (most farmed crop by municipality, above 50 percent of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.034***	0.071***	0.033***	0.010***	0.017***	0.010***
	(0.002)	(0.008)	(0.002)	(0.001)	(0.001)	(0.001)
I [La Niña=1]	-0.093***	0.060	-0.098***	-0.038**	-0.015	-0.036**
	(0.029)	(0.094)	(0.030)	(0.017)	(0.015)	(0.017)
I [El Niño=1]	-0.052	0.032	-0.055	0.028	-0.003	0.032
	(0.036)	(0.119)	(0.037)	(0.021)	(0.018)	(0.022)
L.I [La Niña=1]	0.132***	0.012	0.136***	0.063***	0.001	0.064***
	(0.029)	(0.094)	(0.030)	(0.017)	(0.015)	(0.017)
L.I [El Niño=1]	0.087**	0.193	0.084**	0.008	-0.011	0.009
	(0.036)	(0.119)	(0.037)	(0.021)	(0.018)	(0.022)
Observations	2,375	2,375	2,375	2,375	1,828	2,375
Municipalities	22	22	22	22	22	22

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A7: The effects of El Niño and La Niña phenomena on rice-oriented municipalities most farmed crop by municipality, above 50 percent of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.089***	0.234***	0.075***	0.024***	0.022***	0.023***
	(0.003)	(0.010)	(0.003)	(0.001)	(0.002)	(0.001)
I [La Niña=1]	-0.055	0.082	-0.041	-0.046***	-0.055**	-0.030
	(0.042)	(0.121)	(0.044)	(0.017)	(0.027)	(0.018)
I [El Niño=1]	0.028	-0.362**	0.064	-0.007	-0.072**	0.009
	(0.053)	(0.153)	(0.056)	(0.022)	(0.035)	(0.023)
L.I [La Niña=1]	0.010	-0.203*	0.005	0.018	0.063**	-0.005
	(0.042)	(0.121)	(0.044)	(0.017)	(0.027)	(0.018)
L.I [El Niño=1]	-0.047	0.135	-0.047	-0.036*	0.055	-0.046**
	(0.053)	(0.153)	(0.055)	(0.022)	(0.035)	(0.023)
Observations	1,859	1,859	1,859	1,859	1,702	1,859
Municipalities	16	16	16	16	16	16

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A8: The effects of El Niño and La Niña phenomena on maize-oriented municipalities (most farmed crop by municipality, above 50 percent of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.076***	0.098***	0.071***	0.021***	0.026***	0.023***
	(0.003)	(0.007)	(0.003)	(0.001)	(0.002)	(0.001)
I [La Niña=1]	-0.111***	-0.021	-0.110***	-0.053***	-0.022	-0.056***
	(0.032)	(0.086)	(0.032)	(0.018)	(0.020)	(0.019)
I [El Niño=1]	0.025	0.036	0.025	-0.007	0.014	-0.008
	(0.040)	(0.110)	(0.041)	(0.023)	(0.026)	(0.024)
L.I [La Niña=1]	0.091***	-0.303***	0.116***	0.058***	-0.006	0.055***
	(0.032)	(0.086)	(0.032)	(0.018)	(0.021)	(0.019)
L.I [El Niño=1]	-0.038	-0.088	-0.023	-0.006	-0.021	-0.008
	(0.040)	(0.109)	(0.041)	(0.023)	(0.026)	(0.023)
Observations	2,673	2,673	2,673	2,673	1,944	2,673
Municipalities	24	24	24	24	22	24

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A9: The effects of El Niño and La Niña phenomena on yucca-oriented municipalities (most farmed crop by municipality, above 50 percent of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.183***	0.061***	0.196***	0.060***	0.040***	0.059***
	(0.007)	(0.021)	(0.007)	(0.003)	(0.006)	(0.003)
I [La Niña=1]	-0.155	-0.048	-0.147	-0.056	-0.049	-0.070**
	(0.094)	(0.268)	(0.094)	(0.035)	(0.071)	(0.034)
I [El Niño=1]	-0.059	-0.004	-0.065	0.013	0.046	0.020
	(0.121)	(0.345)	(0.121)	(0.045)	(0.088)	(0.044)
L.I [La Niña=1]	0.067	-0.301	0.093	0.007	-0.010	0.017
	(0.094)	(0.267)	(0.093)	(0.035)	(0.071)	(0.034)
L.I [El Niño=1]	-0.209*	-0.065	-0.191	-0.085*	-0.032	-0.098**
	(0.121)	(0.344)	(0.121)	(0.045)	(0.087)	(0.044)
Observations	703	703	703	703	388	703
Municipalities	6	6	6	6	6	6

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A10: The effects of El Niño and La Niña phenomena on coffee-oriented municipalities most farmed crop by municipality, above 50 percent of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.091***	0.187***	0.088***	0.027***	0.017***	0.027***
	(0.002)	(0.007)	(0.002)	(0.001)	(0.001)	(0.001)
I [La Niña=1]	-0.061**	-0.119	-0.062**	0.006	-0.031*	0.008
	(0.029)	(0.083)	(0.029)	(0.013)	(0.017)	(0.014)
I [El Niño=1]	0.037	-0.061	0.035	0.014	0.016	0.013
	(0.037)	(0.106)	(0.037)	(0.017)	(0.023)	(0.017)
L.I [La Niña=1]	0.036	-0.058	0.046	-0.006	0.046***	-0.009
	(0.029)	(0.083)	(0.029)	(0.013)	(0.017)	(0.014)
L.I [El Niño=1]	0.020	0.037	0.024	-0.013	-0.031	-0.013
	(0.037)	(0.106)	(0.037)	(0.017)	(0.022)	(0.017)
Observations	3,979	3,979	3,979	3,979	2,749	3,979
Municipalities	35	35	35	35	35	35

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

A.2 Regression estimates by crops, including only municipalities above the median of the distribution of the share of total farmed land

Table A11: The effect of weather shocks on potato-oriented municipalities (most farmed crop by municipality, above the median of the distribution of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.034***	0.070***	0.033***	0.009***	0.018***	0.009***
	(0.002)	(0.007)	(0.002)	(0.001)	(0.001)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.007	0.026	-0.007	-0.009	-0.003	-0.008
	(0.017)	(0.055)	(0.017)	(0.010)	(0.009)	(0.010)
I [Precipitation] $\leq$ 20th percentile	0.041**	0.061	0.041**	0.011	0.006	0.013
	(0.017)	(0.055)	(0.017)	(0.010)	(0.008)	(0.010)
L.I [Precipitation] $\geq$ 80th percentile	0.049***	-0.019	0.053***	0.003	0.006	0.002
	(0.017)	(0.055)	(0.017)	(0.010)	(0.009)	(0.010)
L.I [Precipitation] $\leq$ 20th percentile	0.002	0.063	0.002	0.004	0.003	0.005
	(0.017)	(0.055)	(0.017)	(0.010)	(0.008)	(0.010)
Observations	2,375	2,375	2,375	2,375	1,828	2,375
Municipalities	22	22	22	22	22	22

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A12: The effect of weather shocks on rice-oriented municipalities (most farmed crop by municipality, above the median of the distribution of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.085***	0.235***	0.072***	0.025***	0.023***	0.024***
	(0.003)	(0.009)	(0.003)	(0.001)	(0.002)	(0.001)
I [Precipitation] $\geq$ 80th percentile	0.017	0.075	0.006	-0.009	0.006	-0.015
	(0.022)	(0.065)	(0.023)	(0.010)	(0.016)	(0.010)
I [Precipitation] $\leq$ 20th percentile	0.068***	0.105	0.057**	0.018*	-0.005	0.011
	(0.025)	(0.072)	(0.026)	(0.011)	(0.017)	(0.011)
L.I [Precipitation] $\geq$ 80th percentile	-0.015	0.031	-0.021	-0.004	-0.015	-0.007
	(0.022)	(0.065)	(0.023)	(0.010)	(0.016)	(0.010)
L.I [Precipitation] $\leq$ 20th percentile	0.009	0.079	0.010	-0.009	-0.028	-0.009
	(0.025)	(0.072)	(0.026)	(0.011)	(0.017)	(0.011)
Observations	1,978	1,978	1,978	1,978	1,815	1,978
Municipalities	17	17	17	17	17	17

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A13: The effect of weather shocks on maize-oriented municipalities (most farmed crop by municipality, above the median of the distribution of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.079***	0.147***	0.074***	0.020***	0.020***	0.022***
	(0.002)	(0.005)	(0.002)	(0.001)	(0.001)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.038***	-0.125***	-0.033**	-0.018**	-0.008	-0.019**
	(0.014)	(0.036)	(0.014)	(0.008)	(0.008)	(0.008)
I [Precipitation] $\leq$ 20th percentile	0.030**	0.099**	0.025*	0.004	0.011	0.004
	(0.015)	(0.039)	(0.015)	(0.008)	(0.009)	(0.008)
L.I [Precipitation] $\geq$ 80th percentile	0.014	-0.134***	0.017	0.005	-0.018**	0.003
	(0.014)	(0.036)	(0.014)	(0.008)	(0.009)	(0.008)
L.I [Precipitation] $\leq$ 20th percentile	-0.007	0.021	-0.012	-0.011	0.015*	-0.012
	(0.015)	(0.039)	(0.015)	(0.008)	(0.009)	(0.008)
Observations	5,211	5,211	5,211	5,211	3,656	5,211
Municipalities	47	47	47	47	45	47

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A14: The effect of weather shocks on yucca-oriented municipalities (most farmed crop by municipality, above the median of the distribution of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.128***	0.121***	0.130***	0.041***	0.006**	0.043***
	(0.003)	(0.008)	(0.003)	(0.001)	(0.002)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.064***	-0.035	-0.063***	-0.054***	-0.003	-0.056***
	(0.023)	(0.062)	(0.024)	(0.011)	(0.018)	(0.011)
I [Precipitation] $\leq$ 20th percentile	0.033	0.033	0.035	-0.006	0.047***	-0.011
	(0.024)	(0.063)	(0.024)	(0.011)	(0.017)	(0.011)
L.I [Precipitation] $\geq$ 80th percentile	0.026	-0.085	0.032	0.014	0.014	0.011
	(0.023)	(0.062)	(0.024)	(0.011)	(0.018)	(0.011)
L.I [Precipitation] $\leq$ 20th percentile	-0.002	-0.048	0.000	0.009	0.052***	0.006
	(0.024)	(0.064)	(0.024)	(0.011)	(0.018)	(0.011)
Observations	2,579	2,579	2,579	2,579	1,668	2,579
Municipalities	22	22	22	22	22	22

* p < 0.1, ** p < 0.05, *** p < 0.01. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A15: The effect of weather shocks on coffee-oriented municipalities (most farmed crop by municipality, above the median of the distribution of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.088***	0.195***	0.084***	0.024***	0.019***	0.024***
	(0.002)	(0.005)	(0.002)	(0.001)	(0.001)	(0.001)
I [Precipitation] $\geq$ 80th percentile	-0.027**	-0.030	-0.026**	-0.003	0.009	-0.005
	(0.013)	(0.036)	(0.013)	(0.006)	(0.008)	(0.006)
I [Precipitation] $\leq$ 20th percentile	-0.004	-0.017	-0.002	0.009	-0.007	0.008
	(0.013)	(0.037)	(0.013)	(0.006)	(0.008)	(0.006)
L.I [Precipitation] $\geq$ 80th percentile	-0.015	-0.015	-0.017	-0.003	0.007	-0.004
	(0.013)	(0.036)	(0.013)	(0.006)	(0.008)	(0.006)
L.I [Precipitation] $\leq$ 20th percentile	0.018	0.052	0.015	0.012*	-0.002	0.013**
	(0.013)	(0.037)	(0.013)	(0.006)	(0.008)	(0.006)
Observations	6,212	6,212	6,212	6,212	4,256	6,212
Municipalities	55	55	55	55	55	55

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A16: The effects of El Niño and La Niña phenomena on potato-oriented municipalities (most farmed crop by municipality, above the median of the distribution of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.034***	0.071***	0.033***	0.010***	0.017***	0.010***
	(0.002)	(0.008)	(0.002)	(0.001)	(0.001)	(0.001)
I [La Niña=1]	-0.093***	0.060	-0.098***	-0.038**	-0.015	-0.036**
	(0.029)	(0.094)	(0.030)	(0.017)	(0.015)	(0.017)
I [El Niño=1]	-0.052	0.032	-0.055	0.028	-0.003	0.032
	(0.036)	(0.119)	(0.037)	(0.021)	(0.018)	(0.022)
L.I [La Niña=1]	0.132***	0.012	0.136***	0.063***	0.001	0.064***
	(0.029)	(0.094)	(0.030)	(0.017)	(0.015)	(0.017)
L.I [El Niño=1]	0.087**	0.193	0.084**	0.008	-0.011	0.009
	(0.036)	(0.119)	(0.037)	(0.021)	(0.018)	(0.022)
Observations	2,375	2,375	2,375	2,375	1,828	2,375
Municipalities	22	22	22	22	22	22

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A17: The effects of El Niño and La Niña phenomena on rice-oriented municipalities (most farmed crop by municipality, above the median of the distribution of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.085***	0.233***	0.072***	0.025***	0.022***	0.024***
	(0.003)	(0.009)	(0.003)	(0.001)	(0.002)	(0.001)
I [La Niña=1]	-0.049	0.099	-0.036	-0.046***	-0.065**	-0.029
	(0.041)	(0.118)	(0.043)	(0.017)	(0.029)	(0.018)
I [El Niño=1]	0.010	-0.328**	0.043	-0.014	-0.056	-0.000
	(0.051)	(0.149)	(0.054)	(0.022)	(0.037)	(0.023)
L.I [La Niña=1]	0.014	-0.211*	0.011	0.020	0.036	-0.002
	(0.041)	(0.117)	(0.043)	(0.017)	(0.028)	(0.018)
L.I [El Niño=1]	-0.030	0.159	-0.029	-0.027	0.023	-0.035
	(0.051)	(0.148)	(0.054)	(0.022)	(0.037)	(0.022)
Observations	1,978	1,978	1,978	1,978	1,815	1,978
Municipalities	17	17	17	17	17	17

* p < 0.1, ** p < 0.05, *** p < 0.01. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A18: The effects of El Niño and La Niña phenomena on maize-oriented municipalities (most farmed crop by municipality, above the median of the distribution of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.079***	0.144***	0.075***	0.020***	0.020***	0.022***
	(0.002)	(0.005)	(0.002)	(0.001)	(0.001)	(0.001)
I [La Niña=1]	-0.091***	-0.028	-0.088***	-0.039***	-0.038**	-0.041***
	(0.024)	(0.065)	(0.025)	(0.013)	(0.015)	(0.014)
I [El Niño=1]	0.003	0.066	0.003	0.007	0.013	0.006
	(0.031)	(0.083)	(0.032)	(0.017)	(0.019)	(0.018)
L.I [La Niña=1]	0.087***	-0.252***	0.106***	0.044***	0.008	0.041***
	(0.024)	(0.065)	(0.025)	(0.013)	(0.015)	(0.014)
L.I [El Niño=1]	-0.018	-0.098	-0.005	-0.007	-0.027	-0.008
	(0.031)	(0.083)	(0.032)	(0.017)	(0.019)	(0.018)
Observations	5,211	5,211	5,211	5,211	3,656	5,211
Municipalities	47	47	47	47	45	47

* p < 0.1, ** p < 0.05, *** p < 0.01. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A19: The effects of El Niño and La Niña phenomena on yucca-oriented municipalities (most farmed crop by municipality, above the median of the distribution of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.128***	0.120***	0.130***	0.041***	0.006**	0.043***
	(0.003)	(0.008)	(0.003)	(0.001)	(0.002)	(0.001)
I [La Niña=1]	-0.103**	0.078	-0.108***	-0.055***	-0.054*	-0.055***
	(0.040)	(0.108)	(0.041)	(0.019)	(0.030)	(0.019)
I [El Niño=1]	0.013	0.083	0.008	0.014	0.072*	0.016
	(0.052)	(0.139)	(0.053)	(0.024)	(0.039)	(0.024)
L.I [La Niña=1]	0.057	-0.163	0.068	0.035*	0.050*	0.033*
	(0.040)	(0.108)	(0.041)	(0.019)	(0.030)	(0.019)
L.I [El Niño=1]	-0.079	-0.026	-0.075	-0.057**	-0.029	-0.064***
	(0.052)	(0.138)	(0.053)	(0.024)	(0.038)	(0.024)
Observations	2,579	2,579	2,579	2,579	1,668	2,579
Municipalities	22	22	22	22	22	22

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.

Table A20: The effects of El Niño and La Niña phenomena on coffee-oriented municipalities (most farmed crop by municipality, above the median of the distribution of total farmed land)

	Employment			Wages		
	(1) Total	(2) Agricultural	(3) Nonagricultural	(4) Total	(5) Agricultural	(6) Nonagricultural
Year trend	0.088***	0.190***	0.085***	0.024***	0.019***	0.024***
	(0.002)	(0.005)	(0.002)	(0.001)	(0.001)	(0.001)
I [La Niña=1]	-0.045**	-0.078	-0.042*	0.000	-0.024	0.003
	(0.022)	(0.063)	(0.022)	(0.010)	(0.014)	(0.011)
I [El Niño=1]	0.021	-0.050	0.024	0.001	0.003	0.002
	(0.028)	(0.081)	(0.029)	(0.013)	(0.019)	(0.014)
L.I [La Niña=1]	0.046**	-0.120*	0.055**	0.000	0.038***	-0.003
	(0.022)	(0.063)	(0.022)	(0.010)	(0.014)	(0.011)
L.I [El Niño=1]	0.015	0.053	0.016	-0.006	-0.017	-0.006
	(0.028)	(0.081)	(0.028)	(0.013)	(0.019)	(0.013)
Observations	6,212	6,212	6,212	6,212	4,256	6,212
Municipalities	55	55	55	55	55	55

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions estimates include municipal–level and month–level fixed effects. Source: Institute of Hydrology, Meteorology and Environmental Studies and Ministry of Health and Social Protection.