

# **What is the Impact of Drought on Prices? Evidence from Ethiopia**

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## *Abstract*

The impact of drought on household welfare is the cumulative effect of crop loss and price changes in a local economy that are triggered by this initial loss. This paper combines data on monthly grain prices and wages in 82 retail markets over 17 years with data on district-level weather shocks to quantify the impact of drought on local prices. In an agrarian economy like Ethiopia, weather shocks affect not only grain supply, but also demand by reducing household income. The results show that the supply side effects tend to be larger than demand side effects and hence weather shocks increase grain prices, but there is clear seasonality in these impacts. On average during the period studied a 10 percent loss in yields caused grain prices in the months following harvest to increase by 1 percent but this effect dissipated until no significant effect on grain prices was observed 6 months after the shock is realized. The impact of drought then fell further and caused a small but significant deflationary impact in the months prior to the new harvest. The impact of weather shocks on grain prices has fallen over the period considered. The impact of weather shocks on prices was more than three times larger prior to 2002 than after 2007 such that now drought shocks have very little impact on prices. Improvements in market access and better management of drought could explain the attenuation of this impact. The attenuation of this impact was more pronounced in districts where improvements in access to markets were the strongest, where a safety net was introduced and where food aid was better coordinated with weather shocks. Cash transfers do not appear to have inflationary effects on grain prices during times of drought. Wage data suggests that local droughts do not have an impact on nominal wages.

**Keywords:** Weather shocks, grain markets, seasonality, transfers, roads

## 1. Introduction

Wellbeing in Ethiopia, as in many countries in sub-Saharan Africa, has historically been vulnerable to drought. Ethiopian farmers rely almost entirely on rain-fed agriculture and seasonal rainfall is volatile in large parts of the country. Over the last fifty years Ethiopia has experienced 15 droughts. Drought has a direct effect on poverty and conversely good rainfall has been shown to be an important driver of agricultural growth and rural poverty reduction (Dercon, 2004; Little *et al.*, 2006; Carter *et al.*, 2007; Gilligan and Hoddinott, 2007; Demeke *et al.*, 2011; Dercon and Porter, 2014; Thiede, 2014; World Bank, 2015). The consumption levels of those reporting a serious drought were found to be 16 percent lower than those of the families not affected, and they were still experiencing lower consumption growth many years later (Dercon, 2004). A moderate drought, defined as a rainfall shortfall of 30 percent, reduces growth in agricultural incomes by 15 percent on average and increases poverty by 13.5 percent (World Bank, 2015).

The impact of drought on household welfare is the cumulative effect of a household's crop loss and a series of entitlement failures in a local economy that are triggered by this initial loss (Sen, 1981; Devereaux, 2007). Whilst much of the literature on the impact of drought has focused on its cumulative welfare impact, a better understanding of the progression of entitlement failures helps identify the entry points at which the impact of drought may be reduced. Devereux (2007) characterizes four sequences of entitlement failure: first, production fails as a result of the rains failing; then labor markets fail as households are less and less able to find work opportunities on other farms or in off-farm activities; then commodity markets fail as grain prices increase and prices of liquid assets decrease. Finally, transfers fail as households cannot rely on the support of others in their network also facing the same constraints in meeting everyday basic needs.

This paper examines the impact of drought on local markets, quantifying the impact of drought on grain prices and unskilled wages in local markets in the 12 months following the failure of rains. By estimating the impact for each month following the rain failure it provides information on the timing of the effect, and thus when intervention may be needed to address the entitlement failures that result from commodity or labor markets failing.

In an agrarian economy like Ethiopia, weather shocks affect not only grain supply, but also demand by reducing household income. The ultimate impact on prices is an empirical question. An analysis of the macroeconomic impact of agricultural production on prices finds that drought-induced agricultural supply shocks have an inflationary impact: during the drought years of 1984-85 and 2003, the inflation rate reached 18 and 16%, respectively (Durevall *et al.* 2013). Papers have examined the impact of droughts on local prices in other settings. Baffes *et al.* (2015) found that weather shocks, measured by changes in vegetation index, strongly affect local prices in Tanzania, especially in areas that are isolated and have limited access to regional and national markets. Similarly, Brown and Kshirsagar (2015) used changes in vegetation index to capture rainfall shocks and their effects on local prices in 51 countries, and found that the effects of local weather conditions on local prices are more pronounced than the influence of international prices. Prices in 19% of the 554 markets included in their analysis were affected by weather shocks, and only in 4% of these markets, local prices were impacted by shocks in international markets. In Niger, extreme rainfall increases prices in markets in low-supply regions, increasing price dispersion between low and high supply regions (Aker, 2008 and 2010).

We match monthly data on retail prices of six cereals (teff, wheat, maize, sorghum, barley, and African millet) and wages of unskilled laborers in 82 markets over 17 years to data on district

level rainfall data. We find that the impact of the weather shock on grain prices is largest immediately following harvests in December. On average a 10 percent loss caused grain prices from January to May to increase by about 1 percent. From May to October the impact of the rainfall shock on grain prices gradually dissipated, perhaps on account of the demand effect of drought becoming increasingly important as households enter the period when income losses are most severe. At the end of the lean season prior to the new harvest becoming available the impact of drought on grain prices was slightly but significantly negative. In contrast, unskilled nominal wages are not impacted by weather shocks, implying that the real value of wages falls in the immediate aftermath of harvest when food prices rise.

In addition to providing a robust estimate of the magnitude and timing of the impact of drought on local grain prices we also examine whether this has changed over time and in particular whether as Ethiopia has developed it has become more effective in reducing any untoward impact of drought on commodity and labor markets. Ethiopia has experienced a prolonged period of particularly fast development in the timeframe of this study. As part of this development it invested significantly in roads and in developing institutions to respond to drought. The federal and regional road network increased from 26,500 km in 1997 to 100,000 km in 2015 (World Bank, 2016) and this occurred at the same time as mobile phones became available, both of which contributed to substantially better market integration (Minten *et al.*, 2014). In 2005, it established one of the largest safety net programs in sub-Saharan Africa—the Productive Safety Net Program (PSNP)—aimed at addressing food insecurity in the historically drought-prone regions of the country. Although household incomes have remained predominantly agrarian, significant agricultural growth and modernization has been experienced by many (Bachewe *et al.*, 2015). For a number of reasons then we may not expect drought to have the same impact on local prices in 2013 as in 1997. Indeed we find that the impact of weather shocks on grain prices was more than three times larger prior to 2002 than after 2007. After 2007 drought has almost no impact on grain prices, inflationary or deflationary.

Finally, we explore what policy interventions may be behind the reduced impact of drought on grain prices in order to offer lessons on how to mitigate drought-induced commodity market failures. There are a number of reasons as to why this entitlement failure may be smaller in today's Ethiopia than in the past. We explore whether changes over time have been more rapid in parts of the country where connectivity has improved, where agriculture has modernized more quickly, or in districts where a safety net has been introduced.

Improved market access can attenuate the effects of localized drought on grain prices as it reduces transaction cost of shipping grains from other areas that are not affected by drought. In Tanzania, the impact of weather shocks on local prices is less pronounced in well-connected markets (Baffes *et al.*, 2015). Similarly, Burgess and Donaldson (2010) find that after Indian districts obtained railroad access, the intensity of famines in 1875-1919 resulting from rainfall shocks decreased significantly. Data from Schmidt and Kedir (2009) are used to assess whether changes in the impact of weather on prices have been more pronounced in areas where gains in connectivity have been greater. We find that attenuation was more pronounced in districts where improvements in access to markets were the strongest. This is consistent with the notion that better market integration may have been one of the driving forces behind these changes, although we cannot rule out that other changes took place in those areas at that time to also contribute to the change.

Transfers (both in-kind and cash) increase household income and hence demand and prices,

but when transfers are provided in-kind, they also increase supply and hence could decrease prices. In Ethiopia transfers to poor households increase in times of drought, both through the PSNP and through food aid, so these effects may be particularly pronounced. A handful of previous studies have examined the effects of in-kind and cash transfers on grain markets and prices (Ferrière and Suwa-Eisenmann, 2015; Gelan, 2007; Tadesse and Shively, 2009), but none of these studies focus on the role of transfers in influencing grain prices during droughts. We examine whether being in a PSNP district is associated with prices having a larger or smaller effect, and whether this varies depending on whether the transfers are provided in food or cash. In addition we examine emergency food aid transfers since 2005 and determine whether price impacts have been different in districts in which food aid has been more highly correlated with rainfall shocks. The results show that drought has come to have less of an impact on prices in districts where the PSNP was established and where food aid was more highly correlated with weather shocks. Cash transfers do not appear to be having untoward effects on prices during times of drought. We do not observe food aid having a larger impact in districts where its provision has been more highly correlated with rainfall shocks.

We examine whether the relationship between weather shocks and prices has been influenced by agricultural modernization by differentiating parts of the country where modernization was particularly rapid (as measured by increase in fertilizer adoption). We did not find any difference suggesting that the modernization of agricultural production was not a driver of the attenuation observed.

The rest of the paper is organized as follows. Section 2 provides more context on agricultural production and markets in Ethiopia. Section 3 presents theoretical motivation that establishes a link between weather shock and prices, and puts forward empirical hypotheses tested in this study. Section 3 describes the data in detail. Section 4 presents the empirical findings. Section 5 concludes and draws policy implications.

## **2. Context: grain markets and safety nets in Ethiopia**

Agriculture is the predominant source of income in rural Ethiopia with 80 percent of households citing agriculture as their main source of income. Nearly all households in Ethiopia (92 percent) own some land, and the majority of agricultural income is earned through self-employment (World Bank 2015).<sup>1</sup> Only 8 percent of households in rural areas report earning wage income. Agricultural production is predominantly in cereals and is highly dependent on rainfall. Less than one percent of cultivated land is irrigated and as a result the amount and timing of rainfall greatly influence yields and total production. Ethiopia has a diverse agroecology with five distinct agro-ecological zones and a number of micro-climates within those. Some parts of the country experience two seasons reliably each year, others only one season. The rainfall conditions experienced vary across and within zones with some areas experiencing drought conditions whilst others harvest above average production. Section 4 provides more details on this.

The Government of Ethiopia has had a strong policy focus on encouraging productivity growth in small-holder cereal farming during this period in the Agricultural Development Led Industrialization strategy, and its later formulation in the PASDEP and the Growth and Transformation Plans. As part of this strategy the government has spent considerable resources

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<sup>1</sup> All land is owned by the state, but households are granted land user-rights.

supporting cereal intensification of smallholder farmers, for example through investments in rural roads, agricultural extension and supporting fertilizer distribution. Ethiopia experienced substantial yield growth in cereals from 2005 onwards. Fertilizer use increased during this time, although there was little reported increase in the use of improved seeds (1 to 4 percent of cultivated land). A large increase in extension services improvements in market access on account of road construction, higher education levels and good incentives for investing in improved inputs and good weather are considered drivers of increased input use and yield growth (Bachewe *et al.*, 2015).

Agriculture is also an important driver of non-farm growth. Only one in five rural households report deriving income from rural non-farm activities, about half the proportion as in other surveyed countries in SSA (Naude and Nagler, 2014). The most commonly cited constraint to starting and operating non-farm enterprises is lack of demand constrained by strong seasonality in agricultural incomes and the localized nature of sales (Loening *et al.*, 2008; Jolliffe *et al.*, 2014).

Nearly all cereal consumption in Ethiopia is domestically produced, and Ethiopia exports very little cereal production. Given the agro-ecological variation, there is considerable specialization in grain production and consumption across space. Six main grains are produced and consumed: teff, wheat, maize, sorghum, barley, and millet. In general markets in the west and south are supply markets and markets in the north and east are deficit markets although the supply of teff is more spatially diffuse than this (Minten *et al.*, 2014). Grain markets were fully liberalized in Ethiopia in 1990, but although grain markets were competitive they were not particularly efficient, with high costs of transacting for commodities, particularly search. Distances travelled by individual traders were limited (Gabre-Madhin, 2001). As a result, Minten shows that in 2001 only half of the main markets for teff, maize, sorghum and barley were integrated. Substantial changes through the 2000s caused marketing margins to fall considerably and improved market integration.<sup>2</sup> By 2011 83 to 100 percent of markets were integrated for all varieties of teff, wheat and maize (barley and sorghum saw less improvement).

Minten *et al.* (2014) highlight a number of factors that could have contributed to this structural shift in markets in addition to the increased supply of cereals: increased urban demand as a result of urbanization and rising urban incomes, reductions in transportation costs, and the introduction of mobile phones. Urbanization has been increasing but more than four fifths of the population still reside in rural areas. Although this was a time of rising fuel prices (as the government gradually reduced the subsidy on fuel), transportation costs fell as a result of a much expanded road network and increased trucking capacity. The national road network expanded from 26,500 km in 1997 to 100,000 km in 2015. Figure A.1 in the annex shows the length of roads rehabilitated from 1992 to 2011. Investment was increasing throughout this period, particularly from 1995. Even still road density, at 1 km per 1,000 people, is still one of the lowest in Africa. The introduction of mobile phones increased access to information on prices and reduced the cost of search. Gabre-Madhin (2001) estimated that search costs comprised 19 percent of total marketing and transaction costs in 1996 when no mobile phones were available. By 2012 all traders reported using a mobile phone in their business (Minten *et al.*, 2014).

In this paper we examine how the impact of weather on local prices has changed given these

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<sup>2</sup> Some examples from Minten *et al.* (2014): the price difference of wheat from Bale Robe (a supply region) to Addis Ababa fell from 32 percent in 2001 to 2005 to 18 percent in 2006-2011, and the price difference of maize from Addis Ababa to Dire Dawa (a deficit region) fell from 39 percent in 2001 to 2005 to 17 percent in 2006 to 2011.

substantial structural changes in the performance of grain markets over time. We also examine whether changes have been larger for places that have seen increased access to urban areas as a result of urban growth and improvements in road networks.

In addition to changing grain markets, the management of drought has changed considerably during the period analyzed in this paper. In the past drought was managed through the provision of food aid to households in food insecure districts. However, the food aid distribution was often ad hoc, late and poorly targeted. Ethiopia has transitioned from a system of emergency food aid to one in which many vulnerable households are covered under a safety net program, the PSNP. The PSNP was introduced in 2005 in the most food insecure districts in Ethiopia. The PSNP comprised 1% of GDP in 2010/11, and it is one of the largest safety net program in Sub-Saharan Africa. The immediate direct effect of transfers provided to rural households in the PSNP has reduced the national poverty rate by 2 percentage points (World Bank 2015). The PSNP has also had an effect on poverty reduction above and beyond the direct impact of transfers on poverty. PSNP transfers have been shown to increase agricultural input use among some beneficiaries thereby supporting agricultural growth (Hoddinott *et al.*, 2012).

The changing management of drought may also have had an impact on the relationship between weather and local prices and may drive some of the changes observed in the relationship. We also examine whether the changes observed in the drought-price relationship are different in districts in which the PSNP was introduced.

### 3. Theoretical Motivation and Empirical Approach

#### 3.1. Weather shocks and grain prices

In rural Ethiopia, where the main source of income is agriculture, weather shocks not only affect supply but also demand through their effects on household income. This was well documented by Sen's analysis of the drought of 1973-4 in Wollo in which he highlights that grain prices did not change much given the countervailing effect of these two forces. Grain markets in the country have become increasingly integrated over time (Minten *et al.*, 2014), but high transportation costs in some rural markets mean that prices in a particular market are likely to be greatly dependent on local supply and demand.

When markets are not fully integrated, weather shocks can impact local prices by influencing both supply of and demand for grains. At the extreme, when a market is entirely autarkic as a result of very high transportation costs, prices are entirely determined by local conditions. Grain supply ( $S_{it}$ ) in an autarkic market  $i$  at time  $t$ , where farming is characterized by rainfed smallholder agriculture with limited inter-annual storage, can be represented as a function of price ( $P_{it}$ ), weather conditions during corresponding main harvest season ( $W_{it}$ ) and other supply drivers ( $X_{it}^s$ ):

$$S_{it} = s(W_{it}, P_{it}, X_{it}^s, \varepsilon_{it}^s) \quad (1)$$

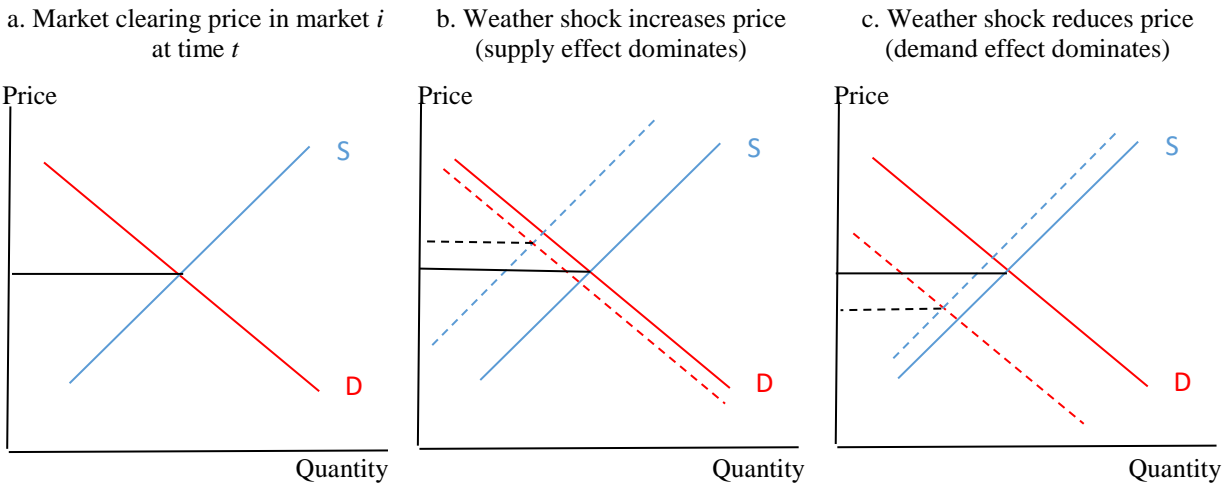
where  $\varepsilon_{it}^s$  captures unobservable random shocks to supply, and  $X_{it}^s$  is a vector of supply shifters such as agriculture inputs, labor and so on in district  $i$ .<sup>3</sup> The demand for grains ( $D_{it}$ ) in market  $i$  at time  $t$  is thus also a function of weather shocks and can be represented as follows:

$$D_{it} = d(W_{it}, P_{it}, X_{it}^d, \varepsilon_{it}^d) \quad (2)$$

where  $X_{it}^d$  is a vector of other demand shifters. The market clearing price is determined by equating  $D_{it}$  and  $S_{it}$  as shown in Figure 1a.

The net impact of weather shocks on the price is indeterminate as it reduces both  $D_{it}$  and  $S_{it}$ . Figure 1b provides one example where the net result is higher prices because the supply effect dominates the demand effect and Figure 1c provides an example where the net effect of weather is lower prices because the demand effect dominates the supply effect. Thus, in a reduced form regression of the impact of weather on prices, the coefficient on weather depends on the relative magnitude of supply and demand side effects of weather shocks. In this study we focus on staple crop prices, and we may expect demand to be relatively inelastic to income in this case. As a result we may expect to find that prices increase as in Figure 1b, but this is something we test in the analysis. The pattern may differ across crops as teff has a high demand elasticity in comparison to sorghum and maize (Tafere et al 2010).

**Figure 1: The impact of weather shocks on prices in an autarkic market**



When markets are not autarkic trade is possible and prices are not determined by local market conditions only. Consider for example, when there is one other market, market  $j$ , with which market  $i$  can trade. When local conditions are such that the local market clearing price in market  $i$  at time  $t$  would be very high relative to market  $j$ , trade from market  $j$  becomes profitable increasing supply and lowering prices. When local conditions are such that the local market clearing price in market  $i$  at time  $t$  would be very low relative to market  $j$ , it becomes profitable to

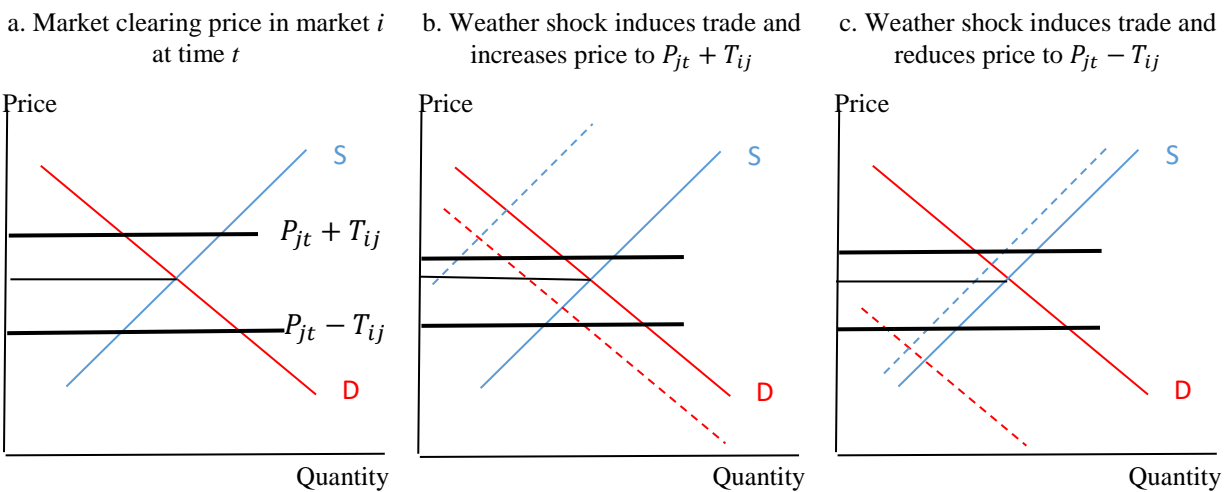
<sup>3</sup> Due to poor storage technologies there is limited inter-annual storage and hence production in time  $t-1$  does not typically affect supply in time  $t$ .



supply other markets with grain from market  $i$ , reducing supply and increasing the price. In this case  $P_{jt}$  and the cost of trade ( $T_{ij}$ ) between market  $i$  and market  $j$  provides a band within which local conditions determine prices and outside of which prices are determined by prices on other markets (Figure 2a): prices will not rise above  $P_{jt} + T_{ij}$  and they will not fall below  $P_{jt} - T_{ij}$ .

What does this mean for the impact of weather on prices? If there is some heterogeneity in weather conditions across markets, as is the case in Ethiopia where weather conditions vary considerably across the country, trade can limit the positive or negative impact of weather on prices. For example, in a market in which the supply effects of weather shocks tend to dominate, a weather shock will cause prices to increase, but they will not increase beyond  $P_{jt} + T_{ij}$  (Figure 2b). In a market in which the demand effects of weather dominate, a weather shock will cause prices to fall, but not below  $P_{jt} - T_{ij}$  (Figure 2c).<sup>4</sup>

**Figure 2: The impact of weather shocks on prices in a market with trade**



### 3.2. Empirical hypotheses

With this in mind we develop four hypotheses that we test with a unique dataset on weather shocks and prices in rural markets in Ethiopia from 1996 to 2012. The dataset combines monthly retail price data for six grains at 82 rural markets with data on weather shock induced yield loss in the rural district surrounding the market.<sup>5</sup> In addition, data on participation of the district in a rural safety net program that started in 2005, the PSNP, and on market access in 2000, 2005 and 2011 is also included.

**Hypothesis 1: The average impact of weather shocks on grain prices is unknown but may fall as the season progresses if demand effects become stronger later in the season.**

<sup>4</sup> This is akin to the insights from Key, Sadoulet and de Janvry (2000) which look at a household decision to participate in a market in the presence of fixed and proportional transaction costs.

<sup>5</sup> Specifically, the percentage of crop yield lost in the woreda due to weather shocks. A detailed discussion on how the yield losses are estimated is presented in the ‘Data Section’.

The impact of weather shocks on supply and demand is unlikely to be uniform across the season. In particular the demand effect may not be observed immediately, unless households immediately adjust their consumption given lower harvests. If this is the case we may observe weather having a stronger positive impact on prices immediately after the harvest which dissipates as demand effects are increasingly observed.

Our first hypothesis, then, is that the average impact of weather shocks on prices across markets in Ethiopia is unknown and depends on whether, on average, demand or supply effects dominate. However, it may fall as the season progresses. We test this by estimating:

$$P_{it} = \sum_{m=1}^{12} (\gamma_m W_{it} * I_m + I_m) + \alpha_i + \beta_t + \varepsilon_{it} \quad (1)$$

where  $W_{it}$  is the weather shock experienced in the district surrounding market  $i$  at time  $t$ .  $I_m$  is a monthly indicator variable,  $\alpha_i$  are district fixed effects, which capture all time-invariant district specific determinants of prices,  $\beta_t$  are year fixed effects, which capture time-varying determinants of prices and  $\varepsilon_{it}$  are other time-varying, location-specific shocks to prices. The coefficients  $\gamma_m$  capture the monthly impact of yield loss on prices. Specifically it is the percent increase in grain prices in month  $m$  as a result of a one percent point increase in yield loss.

**Hypothesis 2: The impact of weather shocks on grain prices has reduced over time as markets have become more integrated and support to drought affected households has become more reliable.**

As section 2 documented, both the structure of marketing and the management of drought changed dramatically since 1997. As markets become more integrated the impact of local conditions (supply or demand) will have less of an impact on local prices. We would thus expect that the impact of weather shocks on local prices has fallen over time. We test this by splitting the time period of analysis into two and estimating:

$$P_{it} = \sum_{m=1}^{12} (\gamma_m^1 W_{it < 2004} * I_m + \gamma_m^2 W_{it \geq 2005} * I_m + I_m) + \alpha_i + \beta_t + \varepsilon_{it} \quad (2)$$

We would expect  $\gamma_m^2$  to be closer to zero than  $\gamma_m^1$ . In addition to comparing 1997-2004 to 2005-2012, we split the time period of analysis into three periods compare 1997-2001, 2002-2007 and 2008-2013.

**Hypothesis 3: The impact of weather shocks on grain prices has reduced more so for markets that benefited more from road investments.**

The drivers of market integration have not been uniformly present across Ethiopia. In particular, improvements in access to markets and access to urban demand has been faster in some parts of the country than in others. We would expect larger reductions in weather-induced price volatility in areas where improvements in market access have been faster. Data on access to markets in 1994 and 2007 is available from Schmidt and Kedir (2009) allowing a comparison of markets that saw significant improvements in market access prior to 2007 with markets that saw less improvement. We test whether the price impact of shocks is lower in markets with greater improvements in market access by estimating:

$$P_{it} = \sum_{m=1}^{12} (\gamma_m^1 W_{it < 2004} * I_m + \gamma_m^2 W_{it \geq 2005} * I_m + \gamma_m^3 W_{it < 2004} * R_i * I_m + \gamma_m^4 W_{it \geq 2005} * R_i * I_m + I_m) + \alpha_i + \beta_t + \varepsilon_{it} \quad (3)$$

where  $R_i$  is an indicator dummy taking the value of 1 if the market was located in a district which saw above median improvements in access to towns of greater than 50,000 people between 1994 and 2007. We test whether  $\gamma_m^4$  is significantly different from zero and of the opposite sign than  $\gamma_m^1$ . However, we note that a significant  $\gamma_m^4$  does not imply that it was the change in market access that caused the attenuation of the impact, as other changes could have been correlated with increased market access also. We do not have any information to suggest that investments would have been higher in places that were more or less poorly integrated so we expect that  $\gamma_m^3$  will be insignificant.

**Hypothesis 4: The introduction of a safety net and better managed emergency food aid has reduced the impact of weather shocks on grain prices by mitigating both demand and supply effects. However, higher inflationary effects are expected in locales where cash transfers have been introduced.**

The demand effect of weather on local grain prices will fall if the sensitivity of household income to weather is reduced. This can occur if households increase the share of their income that comes from non-weather dependent sources. Since 2005, transfers have been made to households in selected districts as part of the PSNP. These transfers increase slightly when weather conditions are bad as there is some provision within the program for benefits to scale when the weather is bad. Some districts have received transfers in kind and some in cash. In addition emergency food aid is provided in times of need, both in districts where the PSNP is operational and districts where it is not. Emergency food aid and in-kind transfers made in the PSNP also affect the local supply of food, but cash transfers have no supply effect at the time of the weather shock, only a demand effect (although transfers may increase supply in general as noted in Section 2).

We examine whether the presence of the PSNP has been associated with a lower impact of weather on local prices by estimating

$$P_{it} = \sum_{m=1}^{12} (\gamma_m^1 W_{it < 2004} * I_m + \gamma_m^2 W_{it \geq 2005} * I_m + \gamma_m^3 W_{it < 2004} * SN_i * I_m + \gamma_m^4 W_{it \geq 2005} * SN_i * I_m + I_m) + \alpha_i + \beta_t + \varepsilon_{it} \quad (4)$$

Where  $SN_i$  refers to districts that have been included in the PSNP. In addition we examine whether those districts where food aid has been more highly correlated with weather shocks have been better able to mitigate any impact of drought on local prices (in these cases  $SN_i=1$  if the district has had above median levels of correlation between food aid and weather shocks over an 8 year period). We examine whether the presence of the cash transfers made as part of the PSNP has been associated with a lower demand effect of weather on prices in markets in those districts causing inflationary supply effects to dominate in these markets. We test this by estimating

$$P_{it} = \sum_{m=1}^{12} (\gamma_m^1 W_{it < 2004} * I_m + \gamma_m^2 W_{it \geq 2005} * I_m + \gamma_m^3 W_{it < 2004} * C_i * I_m + \gamma_m^4 W_{it \geq 2005} * C_i * I_m + I_m) + \alpha_i + \beta_t + \varepsilon_{it} \quad (5)$$

where  $C_i$  is an indicator variable that takes the value of 1 if the district receives cash transfers as part of the PSNP. Districts which did not receive the PSNP are left out of this estimation.

Districts are not selected to receive transfers at random. The PSNP has been targeted to more food-insecure woredas in Ethiopia. Weather shocks may have had a differential impact on prices in these markets even before the PSNP transfers were introduced in 2005. We may therefore expect  $\gamma_m^3$  to be significantly different from zero. After controlling for these differences we expect that the introduction of transfers in PSNP districts would keep demand for goods high mitigating any price impact of lower demand in the wake of a shock. This, however, assumes that there were no other reasons for the relationship between weather shocks and prices to be changing differently in PSNP districts.

#### **Hypothesis 5: Weather shocks have a small negative effect on local wages for unskilled labor.**

In addition we examine whether the wage data recorded for unskilled workers in the monthly retail market survey records weather shocks having an impact on local labor markets. In some contexts, the negative shock to farm incomes that a weather shock implies results in increased supply and reduced demand for labor, both of which depress wages (Deveraux 2007). Labor supply increases as households seek to make up agricultural income losses and demand for labor falls as households have reduced ability to hire labor. If local labor markets are limited, as in rural Ethiopia, we may expect both of these effects to be small. This hypothesis is tested by estimating:

$$wage_{it} = \sum_{m=1}^{12} (\gamma_m W_{it} * I_m + I_m) + \alpha_i + \beta_t + \varepsilon_{it} \quad (6)$$

Where  $wage_{it}$  represents wages in market  $i$  at time  $t$ .

## **4. Data**

In this study, we match monthly retail price data collected on six major cereals (teff, wheat, maize, sorghum, barley, and millet) and wages of unskilled workers in 82 markets from 1997 to 2013 with weather shock data for the same period, the type of transfers households in the district have received in the PSNP since 2005 (if any) and data on access to towns of population greater than 50,000 in 1997 and 2004. The data is introduced in section 3.1. In section 3.2 the key features of weather shocks during this period are described.

### **4.1. Data sources**

*Grain Prices and wages:* We use monthly price data collected in 119 markets from 1996 to 2013 for the analysis.<sup>6</sup> The data comes from the Retail Price Survey, which is collected every month by the Ethiopian Central Statistics Agency (CSA). CSA has selected 119 representative markets to be visited monthly in this survey. The markets surveyed have stayed remarkably

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<sup>6</sup> Occasionally there were months in which prices of certain commodities were not collected on certain markets. This data is treated as missing.

consistent across time. More markets used to be covered prior to 2001 but this data is not included in the analysis. Although there are about 119 markets followed in this survey, this analysis focuses only on those located in rural districts for which crop loss data is available. In addition, most of the analysis is focused on 82 markets that are located in districts which experience only one major rainy season, the *Meher* season. This is done by excluding markets that also experience another rainy season, *Belg*. We use nominal prices (specifically, the log of Birr per kg, or day in the case of wages) in the analysis and include year and monthly dummies to control for inflation and seasonal price patterns.

*Weather shocks:* Data on weather shocks is taken from the Livelihoods, Early Assessment and Protection project (LEAP). LEAP combines ground and satellite rainfall data collected throughout the year to provide rainfall data for each district in Ethiopia. The challenge for our analysis is to aggregate this data into one number which accurately reflects the quality of the rainfall experienced in the district in that season. LEAP uses crop-models to weight rainfall shortages in each 10 day period by how sensitive the crop is to rainfall losses at that moment in the production cycle. It takes into account the crops usually grown and the amount of evapotranspiration normally recorded at that location. This weighted average of rainfall provides an estimate of the proportion of normal yield lost due to poor rainfall in that location in that season. Yield loss estimates are developed for each season in each year from 1996. The yield loss estimates for each season are calculated for 50 km by 50 km pixels, and then aggregated for each district. Yield loss estimates are produced for both the main *Meher* season and also the secondary *Belg* season in the parts of the country that experience this second season. Planting and harvesting dates for each season vary with crop and location, but in general the *Meher* season runs from May to November and the *Belg* season from January to May. For a detailed description of the LEAP system, see Conway and Schipper (2011), and Balzer and Hess (2010). Analysis in Hill and Tsehaye (2014) shows that the yield loss estimates from LEAP are highly predictive of yields measured in the Central Statistical Agency's crop cutting experiments.

*Roads:* We use the Schmidt and Kedir (2009) estimates of time to travel to a town of 50,000 people in 1994 and in 2007 to estimate an average annual reduction in travel time. The distance at each square kilometer in the district is averaged across the district to provide a district average estimate.

*Agricultural production practices:* We use the zonal level measures of the increase in the proportion of farmers that report using fertilizer from 1997 to 2011 estimated in the annual Agricultural Sample Survey conducted by CSA.

*PSNP and emergency food aid:* The PSNP covers about 300 *woredas* in seven regions (Tigray, Amhara, Oromia, SNNP, Afar, Somali, and Harari) and Dire Dawa. The beneficiary *woredas* and the type of transfers they receive has been quite stable since the program was started in 2005.<sup>7</sup> We reviewed the Annual Plans of the PSNP in recent years to identify *woredas* that are recipients of transfer as well as the type of transfers they receive. The transfer that each *woreda* receives is either cash only or a combination of cash and food. On the basis of this review *woredas* were classified into three groups: those that are not in the PSNP, those that receive only cash in the PSNP and those that receive both cash and food in the PSNP. We use these categories in the

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<sup>7</sup> The number of beneficiary *woredas* has changed slightly over time: there were 282, 290, 301, 319, and 319 *woredas* in 2007/8, 2008/9, 2010/11, 2011/12 and 2013/14, respectively (Source: PSNP Annual Plan for the corresponding year).

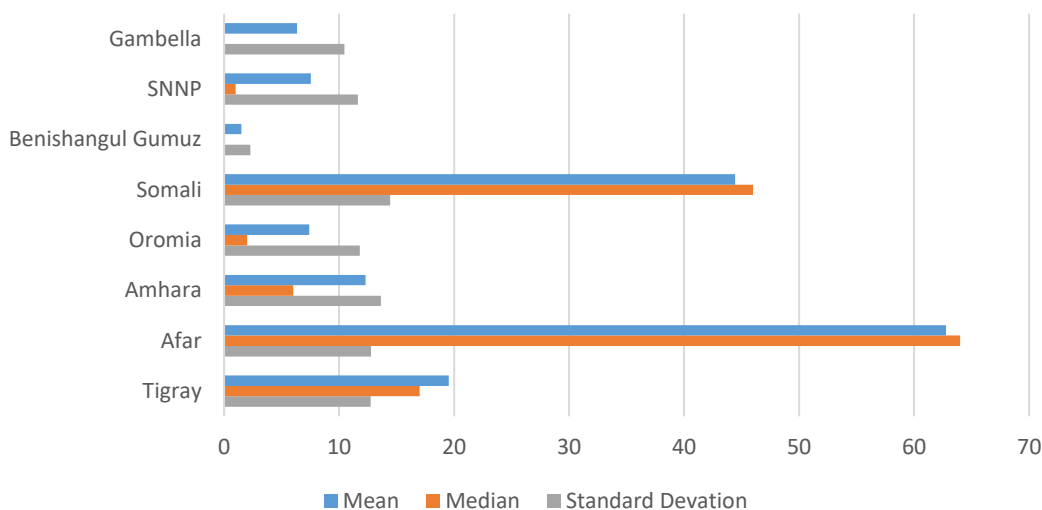
analysis. Data on estimated food aid beneficiaries in each woreda from 2005 to 2012 was used to calculate the correlation between food aid and weather shocks in each woreda.

#### 4.2. Weather shocks across time and space

In this section we provide a brief description of the extent of weather-induced yield losses in Ethiopia and how yield losses vary temporally and spatially. We also describe the trend in grain prices across regions.

Figure 3a presents the mean, median and standard deviation of yield losses during the main *Meher* season in 8 regions over 17 years from 1996 to 2012. There is substantial regional heterogeneity in the amount yield lost. For instance, Afar and Somali regions experience very high yield losses on average, and they respectively lose about 60 and 42 percent of their *Meher* yields on average during this period. On the other hand, Benishangul-Gumuz, SNNP, and Gambela regions experience low levels of yield losses. Despite this variation in the amount of yields lost on average across regions, the standard deviation of yield losses is quite constant across regions (with the exception of Benishangul-Gumuz which experiences very low levels of variation). This suggests that although yield losses are often high on average in Afar and Somali regions they are not more variable than in other regions.

**Figure 3a: Meher yield losses across regions during 1997-2012 period**



Source: LEAP from 1997 to 2012

To explore the temporal variation in weather shock induced yield losses in the country, we present annual average and standard deviation of yield losses from 1996 to 2012 (Figure A.2 in the Annex). There is a considerable year-to-year variation in yield losses. Some years particularly stand out as ones in which bad droughts were experienced: 1999-2003, 2008, and 2012. The share of *Meher* yield lost was the highest in 2001, and the mean yield loss in the country was 18 percent. Another notable result is that the spatial variation in yield losses tends to increase in drought years. This evidence suggests that drought induced yield losses tend to be localized, and some areas are particularly hit hard. This notion of localized droughts is perhaps different to drought in other countries that may have larger widespread effects, and arises on account of the significant variation

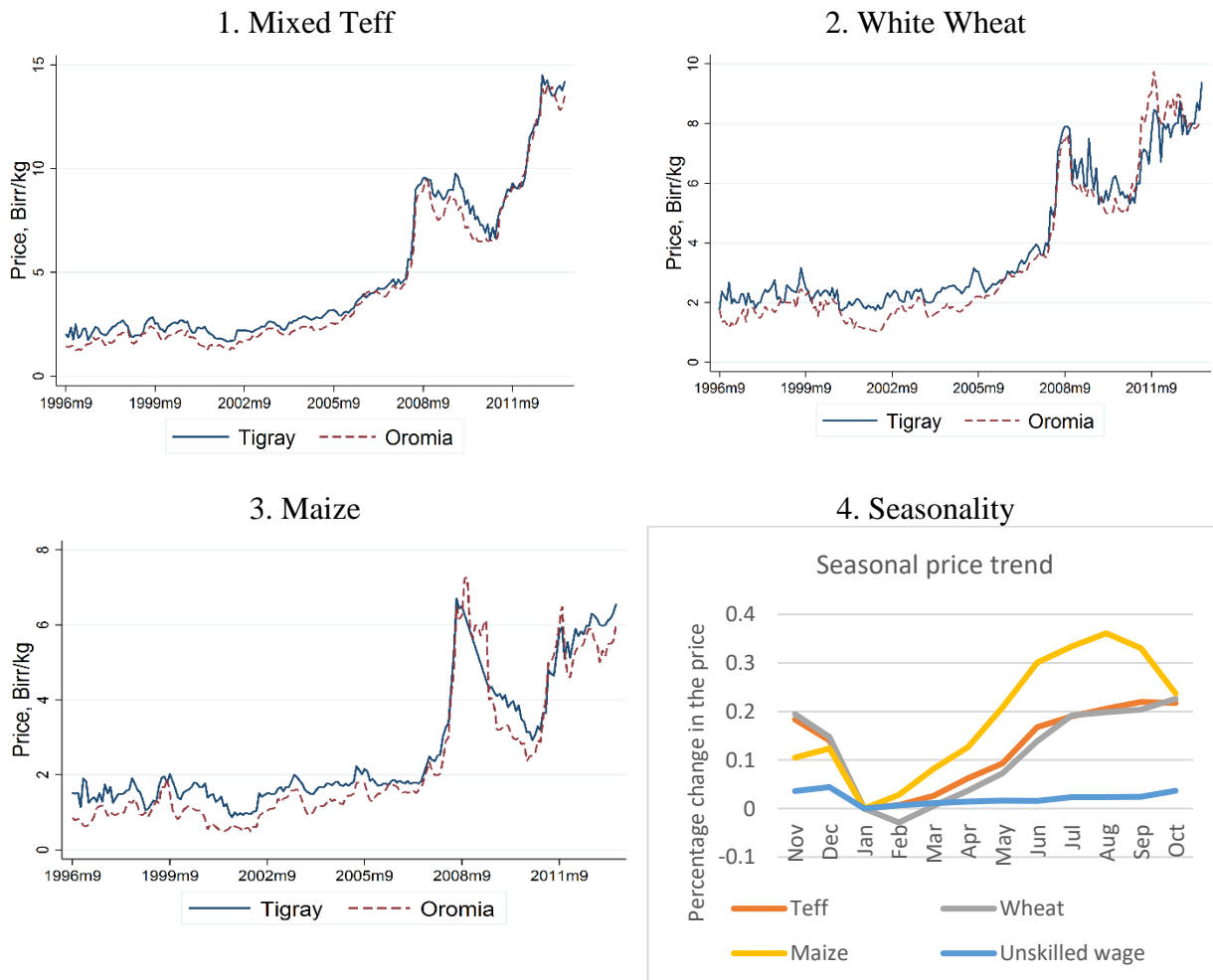
in agro climatic conditions in different parts of Ethiopia. These spatial differences are leveraged to study the effects of localized weather shocks on grain prices.

There are also major year-to-year variations in yield losses in each region. Figure A.3 shows the average yield losses in each region from 1996 to 2012. In almost all regions, 2001 has been the year when the highest yield losses was experienced. For instance, Afar and Somali regions have respectively lost more than three-quarter and half of their yields in 2001. Afar and Somali regions also had the highest yield losses in each year.

## 4.2. Price trends

Nominal price trends for the three most commonly traded commodities—mixed teff, white wheat and maize—for Tigray and Oromia are presented in Figure 4 (prices are averaged across markets in each of these regions). The figures show that grain prices were quite stable until 2007 and they spiked during the 2007/8 commodity price crises. Trends are consistent in both regions. Prices have generally been higher in Tigray than in Oromia throughout the period under consideration, although there is some evidence this difference is falling as found in Minten et al (2014).

**Figure 4: Trends of nominal prices for commonly traded cereals**



Prices experience considerable seasonality. Figure 4.4 presents results for the average difference in price from the January price across all markets in Ethiopia (starting in November). On average, cereal prices are at their lowest in January to March when the full harvest has taken place and much of it has been marketed. Prices steadily increase until July to October which represents the lean season. Prices start to fall in November as early harvesting takes place and the new harvest becomes available for consumption and marketing in parts of the country. Maize prices are somewhat different increasing more steeply until August and starting to fall from August as new production starts to enter the market from the short *Belg* season in which some maize is produced. Prices plateau in November to December until the *Meher* harvest is realized and they fall further, increasing from February. Unskilled wages have the same seasonality as grain prices, but the degree to which they vary is much more muted (although still significant). In the following section we examine how weather shocks cause prices to deviate from this seasonal trend.

## 5. Results

### 5.1. Impact of weather shocks on grain prices and wages

As discussed in the theoretical motivation section, a weather shock induced yield loss has both supply and demand effects. The shortage of supply would have upward pressure on prices, but as households' incomes are tied to agriculture, the yield losses could decrease demand and hence prices. Therefore, the net effects of drought on prices depends on the magnitude of these opposing influences. Given we are considering staples we may expect demand to not fall too much (i.e. to be relatively inelastic). If this is the case the supply effect would dominate and we would see prices increasing. However the magnitude of the supply and demand effect could also vary by time in the season.

The net effect of drought induced yield losses on monthly prices is presented in Figure 5 (results from estimating equation 1).<sup>8</sup> The regression results behind these effects are presented in Table 1. The regressions use the log of the nominal price as the dependent variable and include year and monthly dummies to account for inflation and seasonality in prices. The standard errors are adjusted to account for the fact that errors are serially correlated. The impact is estimated for each month following the *Meher* season harvest from November to October the following year. In Figure 6 the results are presented separately for areas in which there is only one *Meher* harvest (Figure 6a), and also for the three grains for which price data is most commonly collected: mixed teff, white wheat and maize (Figures 6b, 6c and 6d respectively).

The results show that supply side effects are larger than demand side effects throughout the season. However, there is clear seasonality in the impact of the weather shock on prices. In the early harvest period from November to January the impact of the weather on price is not as strong, perhaps as the full impact of the season's rain on the harvest is not yet realized. Prices start to increase, but only marginally—a 10 percent loss in yields increases prices by about 1 percent. By January to May the impact of the weather shock on prices is largest. On average a 10 percent loss in yields causes prices in this period of the year to increase by about 1 percent. From May to October the impact of the weather shock on prices gradually dissipates until the impact becomes slightly but significantly negative. This dissipation could be driven by two factors: the demand

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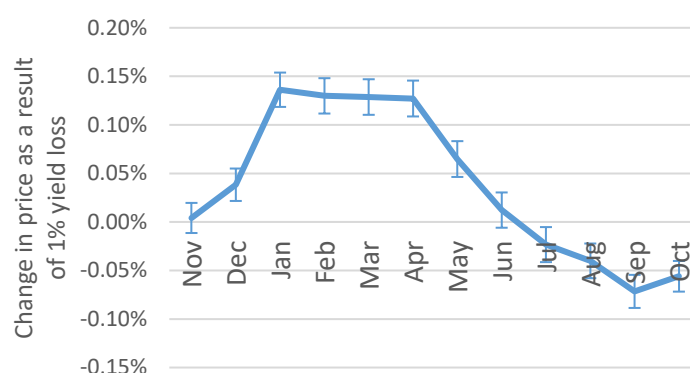
<sup>8</sup> Note that harvest is usually collected starting from November. Therefore, yield losses from the previous planting season is matched with prices starting from the harvest month till the next harvest is collected.



effect resulting from lower incomes could start to increase as households run out of income and demand from grains in local markets is suppressed in comparison to non-drought years. Grains from the minor *Belg* harvest may also become available reducing the supply side shock. The impact of the *Belg* is seen more clearly by comparing areas with a *Belg* harvest to areas with no *Belg* harvest. In areas with a *Belg* harvest the impact on prices does still fall from May to July, but it does not fall further after July, suggesting some of the dissipation is due to the demand effect, but not all.

Figures 6b, 6c and 6d show that this result holds for mixed teff, white wheat and maize. Although the timing of the effects is different, most likely on account of different harvesting periods. Maize is harvested before wheat and teff which is why the impact of the drought on prices is already strong by November, and why there is reversion to the mean in September to October.

**Figure 5: The average impact of weather shocks on grain prices, 1997-2013**



Note: Prices are the log of the nominal price in Ethiopian Birr per kg and yield loss is the percentage of crop yield lost due to rainfall shortage.

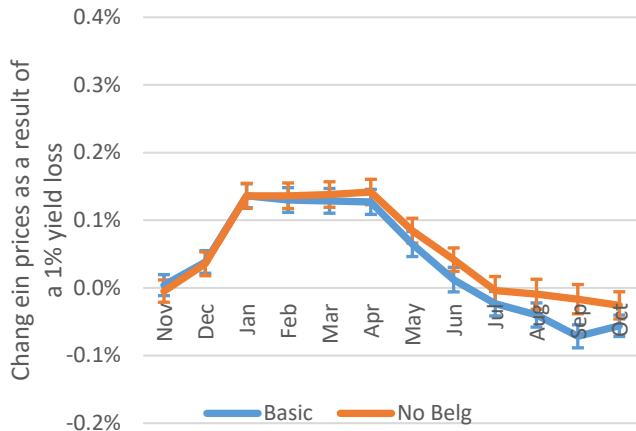
**Table 1: The average impact of weather shocks on grain prices, 1997-2013**

	Impact of 1 percent of yield loss on ln(price) in the following months	P-value
November	0.0000	0.80
December	0.0004**	0.02
January	0.0014***	0.00
February	0.0013***	0.00
March	0.0013***	0.00
April	0.0013***	0.00
May	0.0006**	0.00
June	0.0001	0.50
July	-0.0002	0.20
August	-0.0004**	0.03
September	-0.0007***	0.00
October	-0.0006***	0.00
N	126,306	
Number of markets	82	

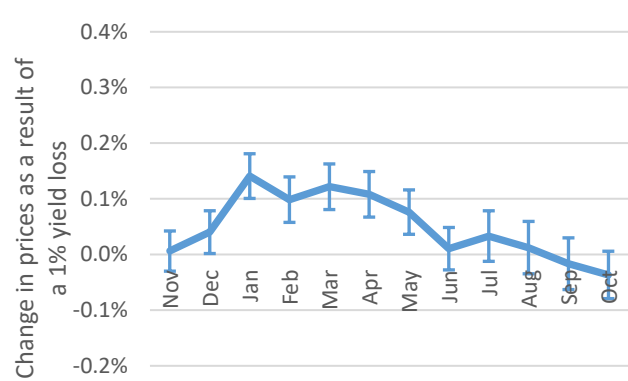
Note: \*\*\* indicates significant at 1%, \*\* significant at 5% and \* significant at 10%. The dependent variable is the log of nominal prices (Birr per kg). The regression includes month and year dummies to control for inflation and seasonality in prices. Grain type (by grade) dummies are included to account for average differences in relative prices across commodities and market fixed effects are included to account for average differences in prices across markets. Robust standard errors that take into account serial correlation in prices were used to estimate the P-values presented.

**Figure 6: The impact of weather shocks disaggregated by season and grain type**

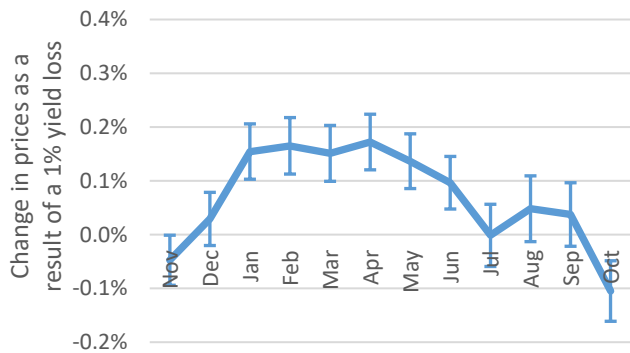
a. Areas with just a Meher season



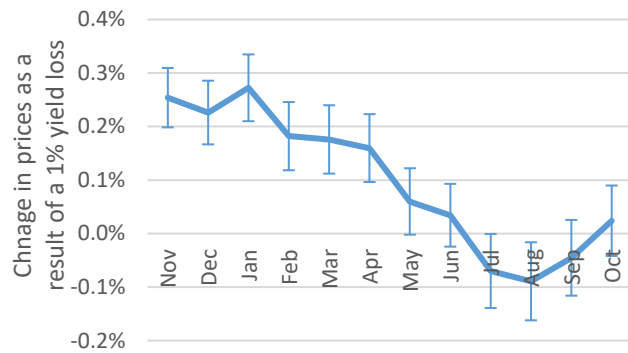
b. Mixed Teff



c. White wheat



d. Maize

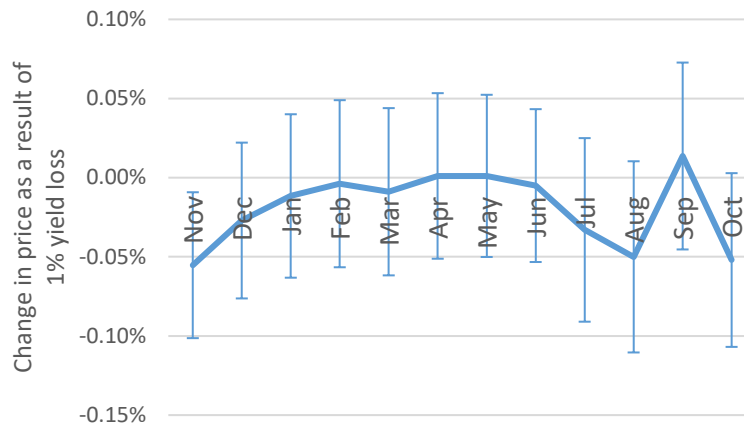


Note: Prices are the log of the nominal price in Ethiopian Birr per kg and yield loss is the percentage of crop yield lost due to rainfall shortage.

In contrast, the impact of weather shocks on unskilled wages is depicted in Figure 7 and Table 2. No significant impact is observed at any point in the season. This result does not change when looking at the impact on different periods of time.<sup>9</sup>

<sup>9</sup> Results also do not change when considering real wages.

**Figure 7: The impact of weather shocks on unskilled wages**



Note: wages are the log of the nominal price in Ethiopian Birr per day and yield loss is the percentage of crop yield lost due to rainfall shortage.

**Table 2: The average impact of weather shocks on wages, 1997-2013**

Impact of 1 percent of yield loss on ln(wage per day) of unskilled labor in the following months		
	Coefficient	P-value
November	-0.001	0.23
December	-0.000	0.58
January	-0.000	0.82
February	-0.000	0.94
March	-0.000	0.87
April	0.000	0.98
May	0.000	0.98
June	-0.000	0.92
July	-0.000	0.57
August	-0.001	0.41
September	0.000	0.82
October	-0.001	0.34
<hr/>		
N	9,428	
Number of markets	82	

Note: The dependent variable is the log of nominal wages (Birr per day). The regression includes month and year dummies to control for inflation and seasonality in wages. Market fixed effects are included to account for average differences in prices across markets. Robust standard errors that take into account serial correlation in wages were used to estimate the P-values presented.

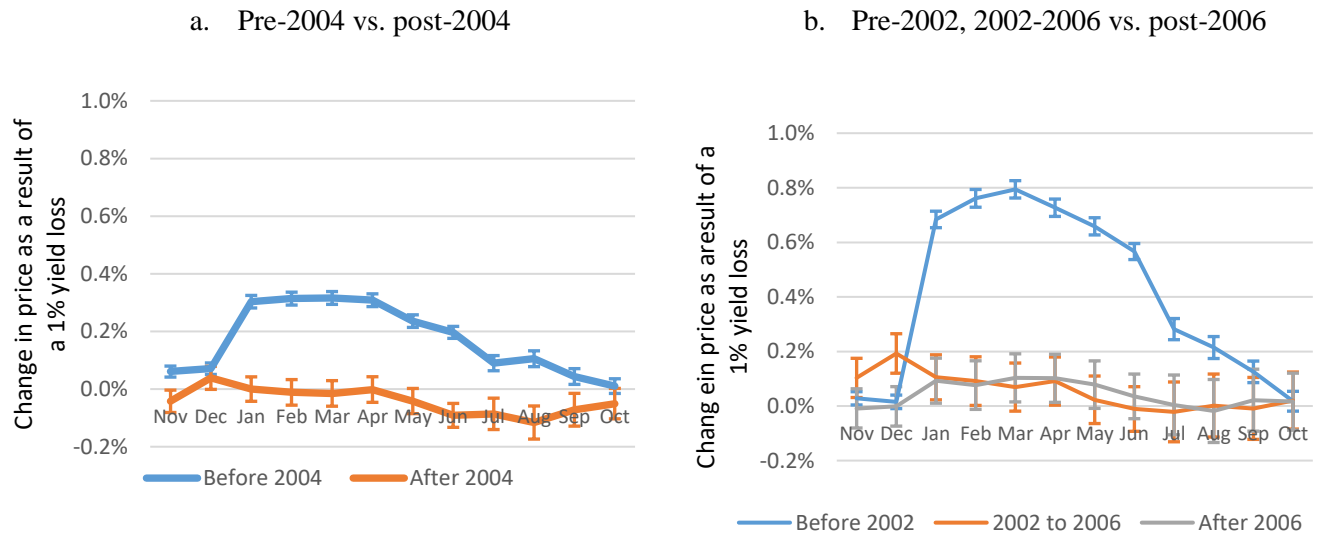
## 5.2. Impact of shocks on grain prices over time

Thus far the results have shown the average impact of weather shocks on prices for the full seventeen year period from 1997 to 2013. However, if markets have been integrating over time in Ethiopia we would expect that the positive impact of local weather shocks on local prices would have been diminishing over time. Similarly, if the government had become increasingly effective at responding to local drought the impact of local weather shocks would also have been diminishing over time. This is tested in Figure 8 by estimating equation 2. Figure 8a shows the impact of weather shocks on grain prices before and after 2004, and Figure 8b shows the impact of weather shocks on grain prices during the periods 1997 to 2001, 2002 to 2006 and 2007 to 2013. Tables 3 and 4 present the regression results behind the graphs in Figure 6.

Over time the impact of weather shocks on prices has fallen. On average, a ten percent reduction in yields induces a 1 percent increase in the January price of grains post 2007, in comparison to a much larger 7 percent increase prior to 2002. After 2007 drought has no inflationary impact on prices outside of the months of January and March. The reduction in the impacts of drought on prices seemed to occur largely after 2002.

In the Annex, Tables A1 and A2 present results examining each of the three main crops—mixed teff, white wheat and maize—one by one. The results show the same pattern: a 3-4 percent impact of a 10 percent rainfall loss prior to 2002 (with the upper estimate for maize) and a negligible, largely insignificant impact of drought on prices after 2002.

**Figure 8: The impact of weather shocks on grain prices over time**



Note: Prices are the log of the nominal price in Ethiopian Birr per kg and yield loss is the percentage of crop yield lost due to rainfall shortage.

**Table 3: The impact of weather shocks on grain prices, pre- and post-2004**

	(1) Before 2004		(2) Difference between pre-2004 and post-2004	
	Impact of 1 percent of yield loss on ln(price)	P-value	Impact of 1 percent of yield loss on ln(price)	P-value
November	0.001**	0.00	-0.001***	0.00
December	0.001**	0.01	0.000*	0.13
January	0.003***	0.00	-0.003***	0.00
February	0.003***	0.00	-0.003***	0.00
March	0.003***	0.00	-0.003***	0.00
April	0.003***	0.00	-0.003***	0.00
May	0.002***	0.00	-0.003***	0.00
June	0.002***	0.00	-0.003***	0.00
July	0.001**	0.00	-0.002***	0.00
August	0.001**	0.00	-0.002***	0.00
September	0.000	0.11	-0.001***	0.00
October	0.000	0.69	-0.001**	0.03
N	126,306			
Number of markets	82			

Note: \*\*\* indicates significant at 1%, \*\* significant at 5% and \* significant at 10%. The dependent variable is the log of nominal prices (Birr per kg). The regression includes month and year dummies to control for inflation and seasonality in prices. Grain type (by grade) dummies are included to account for average differences in relative prices across commodities and market fixed effects are included to account for average differences in prices across markets. Robust standard errors that take into account serial correlation in prices were used. The results are based on a single regression (Equation 2), and the coefficient estimates for each month corresponding to the specified timeframe are presented in columns (1) and (2).

**Table 4: The impact of weather shocks on grain prices, pre-2002, 2002-2006 and post-2006**

	(1) Before 2001		(2) Difference between pre-2001 and 2002-2006		(3) Difference between pre-2006 and post-2006	
	Impact of 1 percent of yield loss on ln(price)	P- value	Impact of 1 percent of yield loss on ln(price)	P- value	Impact of 1 percent of yield loss on ln(price)	P- value
November	0.000	0.25	0.001***	0.00	-0.001	0.00
December	0.000	0.54	0.002***	0.00	-0.002*	0.00
January	0.007***	0.00	-0.006***	0.00	0.000	0.63
February	0.008***	0.00	-0.007***	0.00	0.000	0.59
March	0.008***	0.00	-0.007***	0.00	0.000	0.21
April	0.007***	0.00	-0.006***	0.00	0.000	0.71
May	0.007***	0.00	-0.006***	0.00	0.001	0.03
June	0.006***	0.00	-0.006***	0.00	0.000	0.07
July	0.003***	0.00	-0.003***	0.00	0.000	0.44
August	0.002***	0.00	-0.002***	0.00	0.000	0.57
September	0.001*	0.03	-0.001*	0.01	0.000	0.39
October	0.000	0.63	0.000	0.95	0.000	0.90
N	126,306					
Number of markets	82					

Note: \*\*\* indicates significant at 1%, \*\* significant at 5% and \* significant at 10%. The dependent variable is the log of nominal prices (Birr per kg). The regression includes month and year dummies to control for inflation and seasonality in prices. Grain type (by grade) dummies are included to account for average differences in relative prices across commodities and market fixed effects are included to account for average differences in prices across markets. Robust standard errors that take into account serial correlation in prices were used. The results are based on a single regression, and the coefficient estimates for each month corresponding to the specified timeframe are presented in columns (1), (2) and (3).

### 5.3 Market access and grain price impacts

Improvements in market access have not been even throughout the country and we would expect that areas where improvements in market access have been higher would have seen even larger reductions in weather-induced price volatility. We test whether this is the case by estimating equation 3 and results are presented in Table 5. Indeed we do see that whilst markets that benefited from larger road investments prior to 2007 looked similar to other markets prior to 2007 (column 3), weather shocks in these markets had a smaller impact on prices post-2007 (column 4). These results are consistent with the notion that investments in roads and agglomeration have facilitated market integration in Ethiopia and have reduced the impact of weather shocks on prices. However, if other changes have occurred at the same time as road investments in these districts, this could also explain the estimated relationship.

Another significant area of rural policy in Ethiopia during this period was the focus on intensification of smallholder cereal production, and in particular the expansion of extension services provided. By 2012 Ethiopia had the highest extension agent to farmer ratio in the world. Extension workers provided farmers with information on better crop management techniques and also encouraged farmers to use improved seeds and fertilizers. Although improved seed use did not increase much, fertilizer use expanded quite rapidly during this time (Hill and Tsehaye 2014). It could be the case that the same weather shock has a smaller impact on production and incomes when improved management practices are used. Conversely, it could also be the case that using

fertilizer magnifies the impact of weather shocks as returns to fertilizer are increasing in rainfall (Christiaensen and Dercon 2009). We examine whether prices responded to shocks differently post 2007 in districts with above median increases in fertilizer use during this time, and find that there is no difference (results not shown but available on request). This suggests that it is not policies to support growth in smallholder cereal production that is driving the reduced impact of weather shocks on cereal prices.

**Table 5: Roads and weather shocks over time**

Increase in price as a result of a one percent reduction in yield								
	(1)		(2)		(3)		(4)	
	Before 2007 in low investment areas		Difference after 2007 in low investment areas		Difference between low and high investment areas prior to 2007		Difference between low and high investment areas after 2007	
	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
November	0.001***	0.00	-0.001***	0.01	-0.003***	0.00	0.000	0.49
December	0.002***	0.00	-0.001***	0.00	-0.002***	0.00	0.000	0.33
January	0.002***	0.00	-0.001***	0.00	-0.001	0.19	-0.001**	0.01
February	0.002***	0.00	-0.001***	0.00	-0.001	0.11	-0.002***	0.00
March	0.002***	0.00	-0.001**	0.01	0.000	0.20	-0.001**	0.01
April	0.002***	0.00	-0.001***	0.00	0.000	0.27	-0.001	0.13
May	0.001***	0.00	-0.001**	0.02	0.000	0.83	0.000	0.92
June	0.001***	0.00	-0.001**	0.01	0.000	0.19	0.001	0.26
July	0.001**	0.04	0.000	0.40	-0.001	0.12	0.000	0.99
August	0.001**	0.03	0.000	0.52	-0.001**	0.03	-0.001*	0.08
September	0.000	0.11	0.000	0.37	-0.001***	0.00	-0.001	0.20
October	0.000*	0.07	0.000	0.87	-0.002***	0.00	0.001	0.38
N	126,306							
Number of markets	82							

Note: \*\*\* indicates significant at 1%, \*\* significant at 5% and \* significant at 10%. The dependent variable is the log of nominal prices (Birr per kg). The regression includes month and year dummies to control for inflation and seasonality in prices. Grain type (by grade) dummies are included to account for average differences in relative prices across commodities and market fixed effects are included to account for average differences in prices across markets. Robust standard errors that take into account serial correlation in prices were used. The results are based on a single regression (Equation 3), and the coefficient estimates for each month corresponding to the specified timeframe are presented in columns (1), (2), (3) and (4).

### 5.3. Cash transfers and grain price impacts

Finally, we examine whether the introduction of the PSNP or well managed emergency food aid has helped reduce the impact of weather shocks on grain prices. We first examine the impact of weather shocks on prices in districts in which the PSNP was introduced and then examine the impact of weather shocks on prices in districts in which emergency food aid was well managed. Well managed food aid is defined as an above median correlation of food aid with weather shocks estimated for each district using 8 years of emergency food aid beneficiary data (from 2005 to 2012).

Results are presented in Table 6 and 7. First, we note that the pattern of weather shocks increasing prices prior to 2005 and less so after 2005 is present in non-PSNP woredas and woredas where food aid has not been well-coordinated with weather shocks (columns 1 and 2 of both Tables 6 and 7) which suggests that it is not the PSNP or better managed food aid alone that has driven the time trend observed. Secondly we note that the PSNP was introduced in districts where the impact of weather shocks on prices was *less* inflationary (column 3 of Table 6) whilst food aid was better targeted in districts where the impact of weather shocks on prices was *more* inflationary (column 3 of Table 7). Third, despite these differences, it appears that the impact of weather shocks on prices has reduced more in both PSNP districts and districts where food aid was more correlated with weather shocks, than in other districts (column 4 of Tables 6 and 7). This finding suggests that the introduction of the PSNP and well-timed food aid could have helped reduce the impact of weather shocks on grain prices, although we note that we cannot rule out that other changes in these districts that occurred at the same time drove this result. We do not observe investments in roads to be significantly different between PSNP or well-coordinated food aid districts and other districts, but there could be other factors that we are not accounting for in the analysis.

The impact of well-managed food aid is smaller than that of the PSNP. Whilst this could reflect reality, it could be on account of a poor measure of “well managed” food aid. We have only 8 years of data with which to estimate the correlation. Also food aid is provided not just to districts that receive weather shocks, but also districts that are poorer, and the correlation between weather shocks and food aid alone is not a good indicator of the quality of food aid provision. Also, if food aid has become increasingly well targeted to *all* districts in need over time this could be driving the trend in the impact of weather shocks on prices across time, and we would not be able to pick this up in a cross-district comparison.

We examine whether there is any difference in the impact of weather shocks on food prices in places where the PSNP transfers are provided in cash or in food. As discussed in section 2, we may expect that the impact of weather shocks on prices is higher in districts where cash transfers are made as the dampening demand effect of weather shocks may be reduced in those districts. We test this by estimating equation 5 and results are presented in Table 8. The results show that food transfers were more likely to be provided in places where the inflationary effects of food aid were larger (column 3) but that there is no systematic difference in the impact of weather shocks on areas with PSNP cash and food payments (column 4). This suggests that either the areas selected for cash transfers are well-integrated, or that the payments are too small to exert upward pressure on the price effect of weather shocks. Either the way, the results are encouraging as they suggest that the cash transfers made in the PSNP do not appear to be having untoward effects on prices during times of drought. It may be possible to consider extending the provision of cash transfers to areas that currently receive food transfers, although these areas have in the past seen larger inflationary effects resulting from weather shocks.



**Table 6: Weather shocks and PSNP**

Increase in price as a result of a one percent reduction in yield												
	(1)			(2)			(3)			(4)		
	Before 2005 in non-PSNP district			Difference after 2005 in non-PSNP districts			Difference between non-PSNP and PSNP districts prior to 2005			Difference between non-PSNP and PSNP districts after 2005		
	Coef.		P-value	Coef.		P-value	Coef.		P-value	Coef.		P-value
November	0.002	***	0.000	-0.001	***	0.008	-0.002	***	0.000	0.000		0.564
December	0.002	***	0.000	-0.001	**	0.030	-0.002	***	0.000	0.000		0.363
January	0.003	***	0.000	-0.002	***	0.000	-0.001	***	0.002	-0.001	**	0.033
February	0.003	***	0.000	-0.002	***	0.000	-0.001	***	0.005	-0.001	***	0.004
March	0.003	***	0.000	-0.002	***	0.001	0.000		0.328	-0.002	***	0.001
April	0.002	***	0.000	-0.001	**	0.015	0.000		0.864	-0.002	***	0.000
May	0.002	***	0.000	-0.001	**	0.015	0.000		0.536	-0.002	***	0.001
June	0.002	***	0.000	-0.002	***	0.000	-0.001	**	0.033	-0.001		0.228
July	0.001	**	0.035	-0.001		0.181	-0.001		0.159	-0.001		0.238
August	0.002	***	0.000	-0.003	***	0.000	-0.002	***	0.001	0.002	**	0.045
September	0.001	*	0.073	-0.001		0.174	-0.001	**	0.046	0.000		0.953
October	0.000		0.533	0.000		0.693	0.000		0.931	-0.001		0.155
Observations			126,306									
Number of markets			82									

Note: \*\*\* indicates significant at 1%, \*\* significant at 5% and \* significant at 10%. The regression includes month, year, grain type (by grade) and market fixed effects. Robust standard errors were used to estimate the P-values presented. The results are based on a single regression (Equation 4), and the coefficient estimates for each month corresponding to the specified timeframe and locations are presented in columns (1), (2), (3) and (4).

**Table 7: Weather shocks and emergency food aid**

Increase in price as a result of a one percent reduction in yield												
	(1)			(2)			(3)			(4)		
	Before 2005 in districts with low correlation			Difference after 2005 in districts with low correlation			Difference between districts with high and low correlation prior to 2005			Difference between districts with high and low correlation after 2005		
	Coef.		P-value	Coef.		P-value	Coef.		P-value	Coef.		P-value
November	-0.001	***	0.032	0.000		0.809	0.001	***	0.000	-0.001	***	0.010
December	0.000		0.623	0.000		0.371	0.001	***	0.002	-0.001	**	0.014
January	0.002	***	0.000	-0.003	***	0.000	0.001	**	0.017	0.000		0.743
February	0.002	***	0.000	-0.002	***	0.000	0.001	***	0.002	0.000		0.699
March	0.002	***	0.000	-0.002	***	0.000	0.001	***	0.001	0.000		0.364
April	0.001	***	0.000	-0.002	***	0.000	0.001	***	0.000	-0.001	**	0.023
May	0.001	**	0.003	-0.001	***	0.005	0.001	***	0.008	-0.001	**	0.011
June	0.001	***	0.002	-0.002	***	0.000	0.001	*	0.060	-0.001	*	0.062
July	0.000		0.479	-0.001		0.296	0.001	**	0.014	-0.001		0.179
August	0.000		0.810	-0.003	***	0.000	0.001		0.184	0.001		0.107
September	0.000		0.479	-0.002	***	0.029	0.001		0.145	0.001		0.312
October	-0.002	***	0.000	0.000		0.732	0.002	***	0.000	-0.001		0.152
Observations			126,306									
Number of markets			82									

Note: \*\*\* indicates significant at 1%, \*\* significant at 5% and \* significant at 10%. The regression includes month, year, grain type (by grade) and market fixed effects. Robust standard errors were used to estimate the P-values presented. The results are based on a single regression (Equation 4), and the coefficient estimates for each month corresponding to the specified timeframe and locations are presented in columns (1), (2), (3) and (4).

**Table 8: Food versus cash transfers in the PSNP**

Increase in price as a result of a one percent reduction in yield												
	(1)			(2)			(3)			(4)		
	Before 2005 in cash districts			Difference after 2005 in cash districts			Difference between cash and food districts prior to 2005			Difference between cash and food districts after 2005		
	Coef.		P-value	Coef.		P-value	Coef.		P-value	Coef.		P-value
November	-0.001	***	0.000	0.000		0.827	0.002	***	0.000	0.000		0.732
December	-0.001	***	0.000	0.002	***	0.000	0.003	***	0.000	-0.002	***	0.000
January	0.001	***	0.004	-0.002	***	0.000	0.002	***	0.000	0.000		0.394
February	0.001	***	0.007	-0.002	***	0.000	0.002	***	0.000	0.000		0.486
March	0.001	**	0.029	-0.002	***	0.000	0.002	***	0.000	0.000		0.824
April	0.001	***	0.001	-0.002	***	0.000	0.001	**	0.035	0.000		0.861
May	0.000		0.956	-0.002	***	0.000	0.001	***	0.001	0.000		0.601
June	0.000		0.845	-0.002	***	0.000	0.001	***	0.000	-0.001		0.104
July	-0.001	*	0.055	-0.001		0.338	0.002	***	0.001	-0.001		0.412
August	0.001		0.237	-0.003	***	0.000	0.000		0.968	0.002	**	0.012
September	0.000		0.700	-0.002	**	0.033	0.000		0.466	0.002	**	0.043
October	0.000		0.332	-0.002	**	0.016	0.001		0.175	0.002		0.010
Observations			48,324									
Number of markets			38									

Note: \*\*\* indicates significant at 1%, \*\* significant at 5% and \* significant at 10%. The regression includes month, year, grain type (by grade) and market fixed effects. Robust standard errors were used to estimate the P-values presented. The results are based on a single regression (Equation 5), and the coefficient estimates for each month corresponding to the specified timeframe and locations are presented in columns (1), (2), (3) and (4). The number of markets decreased to 38 because this analysis excludes woredas that were not included in the PSNP.

## 6. Weighted regression results

Thus far, the results have presented the average impact of weather shocks on prices across the 89 markets for which price and weather shock data is available. However, it may be the case that the impact of weather shocks is quite different across markets and an estimate of the simple average impact may not be a particularly relevant statistic.

In some cases it may be more important to know the impact of weather shocks on prices for the average grain produced or traded—giving more importance to the impact of shocks on prices in those areas that produce more cereals. In other cases, it may be more important to know the impact of weather shocks on prices for the average person or the average poor person, giving more importance to the impact of shocks on prices in those areas where more people live, or more poor people live.

Figure 7 compares the unweighted regression results with results that weight the markets by the quantity of the cereal produced in the surrounding zone, and results that weight the markets by the poverty rate of the surrounding zone. The graphs indicate that weather shocks have a more inflationary effect in the average market than in markets in the poorest parts of the country. Markets in poor regions have seen slightly smaller effects of weather shocks on prices, perhaps because demand effects are likely to be larger at lower levels of income, or because supply effects are smaller in poorer places more often characterized by marginal agricultural production.

The impact on the average grain produced, however, is higher than the impact in the average market. Prices are more likely to increase in response to weather shocks in markets located in zones where production is higher, most likely because the supply effect on prices is more pronounced in places where the supply of grain is larger, which makes sense. For wheat and teff the demand effects observed at the end of the season also seem to be larger in these markets. Whilst this paper does not consider the impact of weather shocks on national prices and inflation, these results suggest it may be slightly larger than the local price effect estimated in this paper.

**Figure 7: Weighted price impacts of weather shocks**



Note: Prices are the log of the nominal price in Ethiopian Birr per kg and yield loss is the percentage of crop yield lost due to rainfall shortage. Results are unweighted and weighted by the quantity of the crop produced in the surrounding zone and the poverty rate in the surrounding zone (both averaged over 1997-2012).

## 7. Conclusion and policy implications

Studies on the impacts of drought in Ethiopia have focused predominantly on analyzing the household-level effects by exploring its impacts on food security, poverty, asset holdings, migration decision and so on. In addition to household-level effects, understanding the meso-level impacts of weather shocks is crucial as this is a key mechanism through which droughts influence welfare. The current study is dedicated to analyzing a key meso-level effects of localized weather shocks on grain prices and wages, which in turn affect welfare.

The results show that in grain markets, the supply side effects are larger than demand side effects and hence weather shocks increase grain prices, but there is clear seasonality in the impact. On average across the period studied, a 10 percent reduction in yields as a result of a weather shock caused a 1 percent increase in prices immediately following harvest, but by 6 months after harvest this effect had fallen to zero and it then fell further such that it had a small but significant *deflationary* effect on prices. A number of reasons are posited for this pattern in price effects. As households enter the lean season prior to the next harvest, the demand side effects on prices could become stronger as income shocks are felt more keenly by local farmers. In contrast, weather shocks have no effects on unskilled wages.

As Ethiopia has developed over this period the impact of local weather shocks on local prices has attenuated. This reduction seemed to have occurred largely between 2001 and 2007. There are a number of reasons that could be behind this attenuation. Markets may have become better integrated or the Government may have become more adept at managing droughts over time.

In support of the hypothesis that market integration can account for some of this change we find that this attenuation has been stronger in places where gains in market access have been larger. This finding suggests that measures that improve market access could ease the serious welfare implications that localized droughts might have in rural areas, particularly in the months immediately following harvest. However, other factors are also important for improving the performance of grain markets: for example, improved access to market information through expansion of mobile phone network in rural areas could have contributed to such improvements.

The impact of drought on prices has attenuated more in districts in which the PSNP was introduced than those in which it was not. The PSNP cannot account for all of the change, as significant improvements were also recorded in non-PSNP districts, but it may be the case that the transfers made as part of the PSNP have reduced the grain price impact of weather shocks. Inflationary effects have also been more attenuated in districts in which emergency food aid was more highly correlated with weather shocks, but the difference is smaller than the difference observed for PSNP districts. A comparison of food and cash transfers made in the PSNP shows that cash transfers are not having untoward effects on prices during times of drought. This is important information for policy makers when considering types of transfers to be provided drought affected areas. Cash transfers can be made more cheaply than food transfers and increased in the face of drought more quickly (Clarke and Hill 2013). It brings into question the need for food transfers still to be made in the PSNP, although it remains to be seen whether this finding would translate into areas where food transfers are made.

The tentative policy recommendations from this study would thus be that both investments to improve market integration and to provide safety nets can improve household vulnerability by reducing the inflationary effects of drought in local markets. Transfers can be made in cash in many localities without causing inflationary effects in the presence of drought.

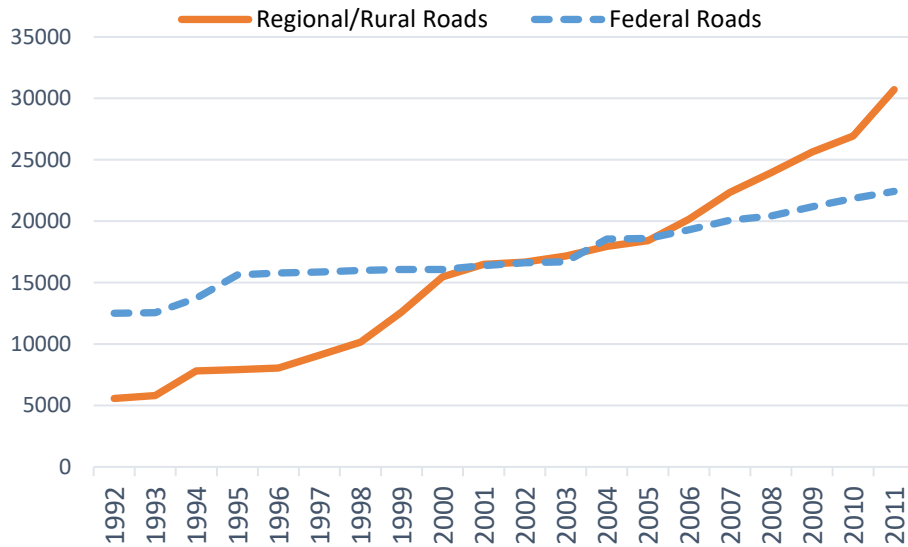
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## Annex

Figure A.1: Length (km) of roads improved in each year by regional and federal road authorities (1992-2011)



Data source: Ethiopian Road Authority (2013)

Figure A.2: Annual National Yield Losses (*Meher* season)

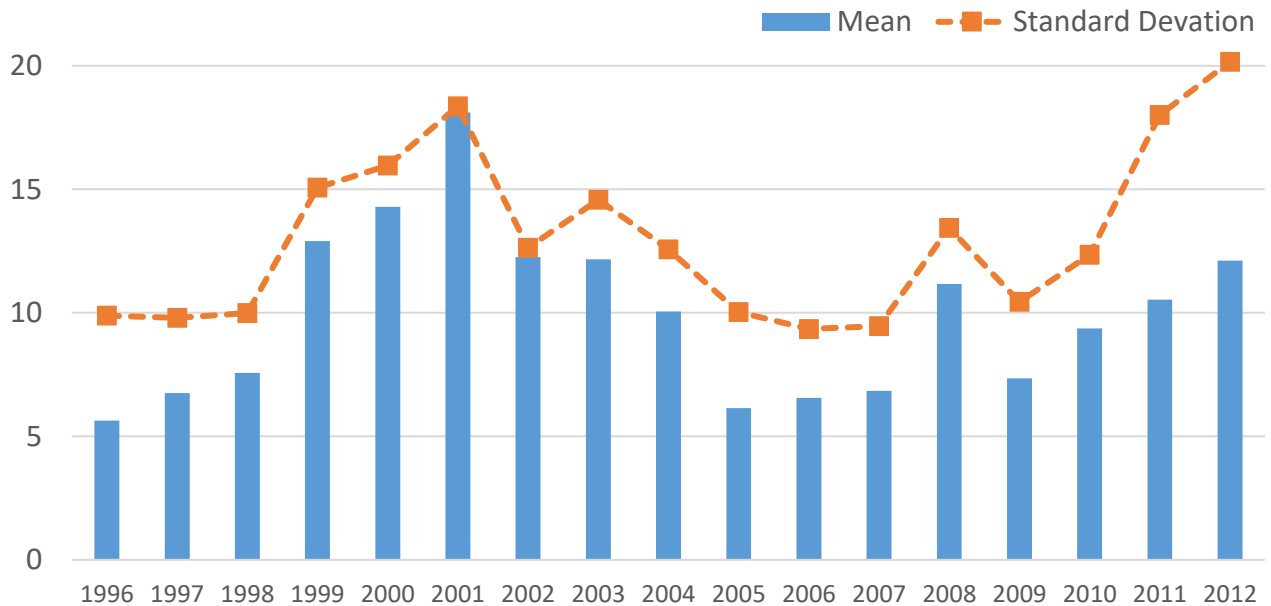


Figure A.3: Historical Average Yield Losses by Region (annual average for *Meher* season, 1996-2012)

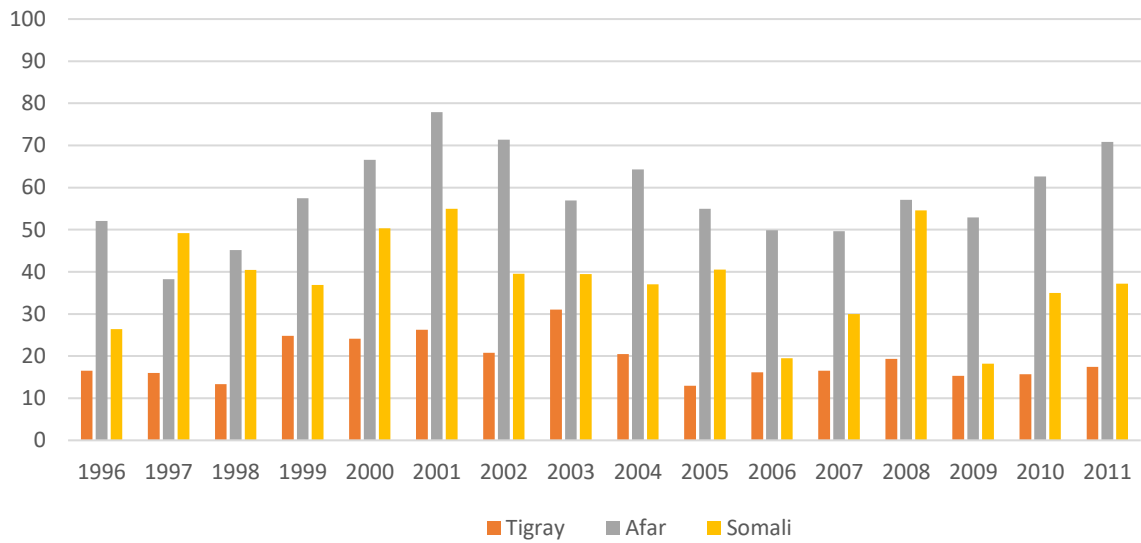
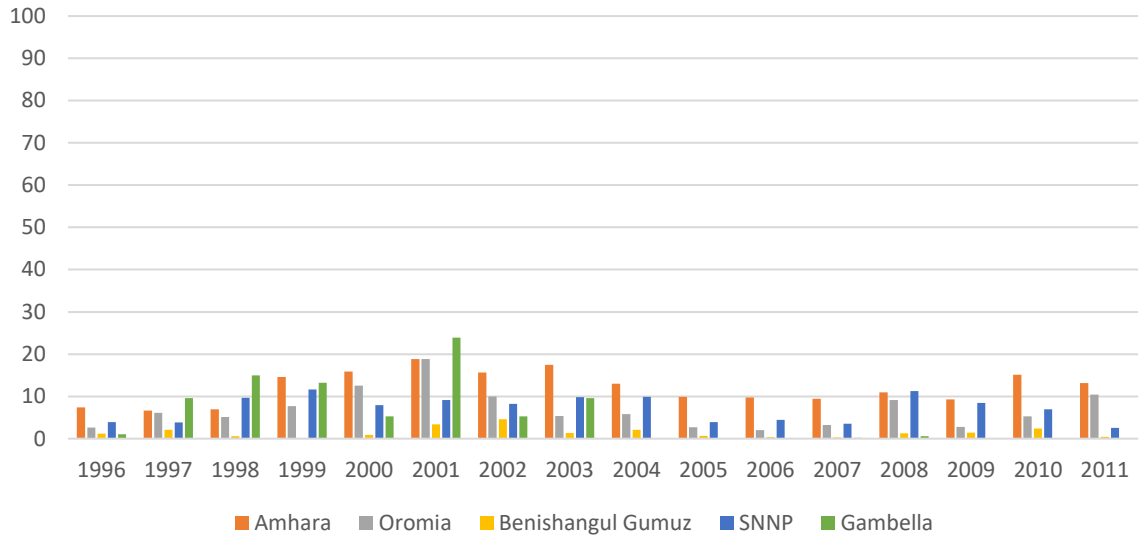




Table A1: The impact of weather shocks (1% yield loss) on grain prices over time  
(pre- and post-2004)

	(1)		(2)		(3)	
	Mixed Teff Coef.	p-value	White Wheat Coef.	p-value	Maize Coef.	p-value
Before 2004						
Nov	0.001	0.14	0.000	0.87	0.003***	0.00
Dec	0.001	0.24	0.001	0.35	0.003***	0.00
Jan	0.003***	0.00	0.003***	0.00	0.004***	0.00
Feb	0.003***	0.00	0.003***	0.00	0.004***	0.00
Mar	0.003***	0.00	0.003***	0.00	0.004***	0.00
Apr	0.003***	0.00	0.003***	0.00	0.003***	0.00
May	0.002***	0.00	0.002***	0.00	0.002***	0.01
Jun	0.001**	0.04	0.002***	0.00	0.002***	0.00
Jul	0.001*	0.06	0.001	0.34	0.000	0.65
Aug	0.001	0.11	0.001**	0.05	0.001	0.40
Sep	0.001	0.33	0.001	0.25	0.001	0.38
Oct	-0.000	0.96	-0.000	0.94	0.001	0.16
Difference between pre-2004 and post-2004						
Nov	-0.001**	0.03	-0.001*	0.08	-0.001**	0.02
Dec	-0.000	0.77	-0.000	0.77	-0.001	0.38
Jan	-0.003***	0.00	-0.003***	0.00	-0.003***	0.00
Feb	-0.003***	0.00	-0.003***	0.00	-0.003***	0.00
Mar	-0.003***	0.00	-0.004***	0.00	-0.003***	0.00
Apr	-0.003***	0.00	-0.002***	0.00	-0.003***	0.00
May	-0.003***	0.00	-0.002***	0.00	-0.002***	0.00
Jun	-0.002***	0.00	-0.002***	0.00	-0.004***	0.00
Jul	-0.002**	0.01	-0.001*	0.07	-0.002**	0.02
Aug	-0.002***	0.01	-0.002**	0.01	-0.003***	0.00
Sep	-0.001**	0.03	-0.001	0.22	-0.002**	0.02
Oct	-0.001	0.26	-0.002**	0.01	-0.002*	0.07
N	10,294		8,951		9,900	
Number of woredas	82		82		82	

Table A2: The impact of weather shocks (1% yield loss) on grain prices over time  
(Pre-2001, 2002-2006 and Post-2006)

	(1) Mixed Teff		(2) White Wheat		(3) Maize	
	Coef.	p-value	Coef.	p-value	Coef.	p-value
<i>Before 2001</i>						
Nov	0.001	0.20	-0.001	0.45	0.003***	0.00
Dec	-0.000	0.58	-0.001	0.36	0.002**	0.05
Jan	0.006***	0.00	0.007***	0.00	0.010***	0.00
Feb	0.007***	0.00	0.006***	0.00	0.010***	0.00
Mar	0.007***	0.00	0.007***	0.00	0.010***	0.00
Apr	0.006***	0.00	0.005***	0.00	0.009***	0.00
May	0.006***	0.00	0.005***	0.00	0.008***	0.00
Jun	0.005***	0.00	0.003***	0.00	0.007***	0.00
Jul	0.003***	0.00	0.001	0.31	0.001	0.40
Aug	0.002**	0.03	0.002*	0.06	0.001	0.64
Sep	0.002**	0.02	0.001	0.58	0.001	0.56
Oct	0.000	0.75	-0.001	0.47	0.000	0.68
<i>Difference between pre-2001 and 2002-2006</i>						
Nov	0.000	0.60	0.001	0.42	0.001	0.50
Dec	0.002***	0.00	0.002***	0.00	0.003***	0.00
Jan	-0.004***	0.00	-0.006***	0.00	-0.007***	0.00
Feb	-0.006***	0.00	-0.005***	0.00	-0.009***	0.00
Mar	-0.006***	0.00	-0.006***	0.00	-0.009***	0.00
Apr	-0.005***	0.00	-0.004***	0.00	-0.008***	0.00
May	-0.006***	0.00	-0.004***	0.00	-0.008***	0.00
Jun	-0.005***	0.00	-0.002***	0.00	-0.007***	0.00
Jul	-0.003***	0.00	-0.001	0.38	-0.001	0.40
Aug	-0.002**	0.04	-0.001	0.20	-0.001	0.62
Sep	-0.002**	0.02	-0.000	0.90	-0.000	0.75
Oct	-0.000	0.74	0.000	0.64	0.001	0.62
<i>Difference between pre-2006 and post-2006</i>						
Nov	-0.001**	0.02	-0.000	0.74	-0.002**	0.01
Dec	-0.002***	0.00	-0.001**	0.03	-0.003***	0.00
Jan	-0.000	0.40	-0.000	0.61	-0.002**	0.03
Feb	-0.001	0.19	0.001	0.50	-0.001	0.35
Mar	0.000	0.83	-0.000	0.65	0.001	0.56
Apr	-0.001	0.24	0.000	0.91	0.001	0.53
May	0.000	0.64	0.001	0.17	0.002***	0.01
Jun	0.001**	0.02	0.000	0.52	-0.000	0.68
Jul	0.001	0.42	-0.000	0.70	-0.001	0.29
Aug	0.000	0.86	-0.000	0.60	-0.001	0.21
Sep	-0.000	0.64	0.000	0.63	-0.001	0.27
Oct	-0.000	0.93	-0.002**	0.02	-0.001	0.47
N	10,294		8,951		9,900	
Number of woredas	82		82		82	