Policy Research Working Paper 9389

What Is the Impact of Weather Shocks on Prices?

Evidence from Ethiopia

Ruth Hill
Habtamu Fuje

WORLD BANK GROUP
Poverty and Equity Global Practice
September 2020

Abstract

The impact of drought on household welfare is the cumulative effect of crop losses and price changes in a local economy that are triggered by these initial losses. 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 and how this impact varies by month after harvest. The results show that price increases occur immediately after the completion of harvest and then dissipate so that inflationary effects are quite low during the lean season, contrary to commonly held views. The impact of shocks on prices is quite low now in Ethiopia—4 percent at its peak post-2005 compared with 12 percent before 2005. In areas of the country where infrastructure investments have been high, there is now almost no inflationary impact of drought on prices. It is not clear whether it is infrastructure investments or something else that has driven that, but it shows that it is possible for rainfall shocks to have no inflationary impacts in low income economies. Inflationary impacts were also reduced more in districts where the Productive Safety Net Program was introduced. Comparing inflationary effects in districts with food versus cash transfers suggests that cash transfers do not have inflationary effects on grain prices during times of drought.

This paper is a product of the Poverty and Equity Global Practice. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at RHill@worldbank.org and HFuje@worldbank.org or Habtamu.fuje@columbia.edu.

What Is the Impact of Weather Shocks on Prices? Evidence from Ethiopia

Ruth Hill* and Habtamu Fuje†

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

JEL Classification: R11, F18, O13, J43

* RHill@worldbank.org

† Habtamu.Fuje@columbia.edu

1. Introduction

Well-being 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 50 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; Deveraux, 2007). While 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 in drought affected communities. First, production fails as a result of the rain failure. Second, because drought affects many households in the community at the same time, labor markets fail: households are less and less able to find employment opportunities on others farms or in off-farm activities. Third, 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 who are also facing the same constraints in meeting everyday basic needs.

This paper examines the impact of drought on local (and hence rural) markets, quantifying its impact on grain prices and unskilled wages in local markets in the 12 months following the failure of rains. By estimating the impact in each month following the rain failure, the analysis 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. The paper thus provides an important contribution to the literature, by providing more detail on the timing of welfare effects after a climatic shock, an area where existing evidence is quite weak. In an agrarian economy like Ethiopia, weather shocks affect not only grain supply, but also demand by reducing household income. The net impact on prices is an empirical question.

Previous studies have examined the impact of droughts on local prices in other settings. Baffes *et al.* (2015) found that weather shocks, measured by changes in the 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 the 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. 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).

However, these papers have considered the average impact and have not examined the timing of these effects and how the price impacts vary throughout the year. As the analyses conducted in this study show, the impact of these shocks is highly seasonal.

We match monthly data on retail prices of six staple 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 annual growing season rainfall.

We find that the impact of the weather shock on grain prices is largest immediately following harvest in January. On average a 1 in 5-year moderate drought caused grain prices from January to May to increase by 9 percent. From May to October the impact of the rainfall shock on grain prices gradually decreases. During the lean season prior to the new harvest becoming available the impact of a moderate drought on grain prices is much lower at 3 percent. The sudden increase in prices at harvest time and the lack of inflationary impacts during the lean season is somewhat counter to commonly held views where the concern is around price increases during a prolonged lean season, not price increases at harvest time itself.

In contrast, unskilled nominal wages are not significantly impacted by weather shocks, implying that the real value of wages falls in the immediate aftermath of harvest when food prices rise. This is contrary to what has been found in India (Jayachandran 2006).

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. 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, basic services, agricultural extension and a rural safety net 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 phone expansion, both of which contributed substantially to 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 parts of the country.[3] Although household incomes have remained predominantly agrarian, significant agricultural growth and modernization have 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 2005 than after. In places where infrastructure investments have been high, drought has almost no inflationary impact post 2005.

Changes in infrastructure over time have been widespread across all parts of the country. It is not clear however that it is infrastructure investments that have driven the change in the impact of weather on prices as infrastructure investments have been non-random. There has also been attenuation in areas where road improvements were lower. Attenuation could have been driven by

[3] The PSNP has a very wide coverage. In 2010, for example, a total 7.4 million Ethiopians in nine regions were targeted to receive benefits. Of these, 1.3 million received cash only and 3.3 million received food only. The remaining 2.8 million received a combination of cash and food transfers (MOARD, 2010). The program uses both administrative and community targeting approaches. The national targeting guidelines, which aim to guarantee timely and adequate transfers to the most food insecure people, allowed for regional and local adaptation (Sharp, 2006).

improvements in market efficiency coming from other factors during this time: for example, increased urban demand, higher trucking capacity or the introduction of cell phones (Minten *et al*., 2014). However, we note that the finding that greater attenuation took place in locations with greater improvements in market access is consistent with analysis from Tanzania that shows that the impact of weather shocks on local prices is less pronounced in well-connected markets (Baffes *et al.*, 2015) and from India. 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.

There is little evidence that the introduction of the PSNP can take credit for the change over time. However, a comparison of districts in which beneficiaries received transfers in kind or in cash yields some interesting insights. 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 focuses on the role of transfers in influencing grain prices during drought periods. We examine whether being in a PSNP district is associated with having a larger or smaller price effect, and whether this varies depending on whether the transfers are provided in food or cash. The results show that districts receiving cash transfers do not experience more inflation during times of drought. In-kind transfers appear to have been well targeted to places where the inflationary impact of drought was higher.

The rest of the paper is organized as follows. Section 2 provides more context on agricultural production and markets in Ethiopia. Section 3 presents the motivation for the empirical questions tested in this study. Section 4 describes the data in detail. Section 5 presents the empirical findings. Section 6 concludes and discusses the 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 most of the agricultural income is earned through self-employment (World Bank 2015).[4] Only 8 percent of households in rural areas report earning wage income. Agriculture is dominated by cereal production and is highly dependent on rainfall. Less than 1 percent of cultivated land is irrigated and, as a result, the amount and timing of rainfall greatly influence yields and total production. Lack of rainfall is the main risk to production. Ethiopia has a diverse agroecology with five distinct agroecological zones and several micro-climatic divisions within those. Some parts of the country experience two seasons every year, others only one season. The rainfall conditions experienced vary across and within zones—with some areas experiencing drought conditions while 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 smallholder cereal farming during this period in the Agricultural Development Led Industrialization strategy, and its later formulation in the PASDEP and the Growth and

[4] All land is owned by the state, but households are granted land user-rights.

Transformation Plan.[5] As part of this strategy, the government has spent considerable resources 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.[6] A large increase in availability of extension services, improvements in market access, higher education levels, good incentives for investing in improved inputs and good weather are considered as major 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. This is about half the proportion as in other countries in SSA (Naude and Nagler, 2014). The most commonly cited constraint to starting and operating non-farm enterprises is lack of demand, which is 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 cereals. Given the agroecological variation, there is considerable specialization in grain production and consumption across space. The six main grains--teff, wheat, maize, sorghum, barley, and millet–are produced and consumed widely. In general, with the exception of teff whose supply is more spatially diffused, markets in the west and south are supply markets, while markets in the north and east are deficit markets (Minten *et al.,* 2014). Grain markets were fully liberalized in 1990. However, even if grain markets were competitive, they were not particularly efficient, with high transaction costs. Distances travelled by individual traders were limited (Gabre-Madhin, 2001). As a result, Minten shows that only half of the main markets for teff, maize, sorghum and barley were integrated in 2001. Substantial changes throughout the 2000s have caused marketing margins to fall considerably and improved market integration.[7] By 2011, 83 to 100 percent of markets were integrated for all varieties of teff, wheat and maize, while barley and sorghum markets saw less improvements.

Minten *et al.* (2014) highlight several factors that could have contributed to this structural shift in markets: increased urban demand as a result of urbanization and rising urban incomes, reduction 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 a fuel subsidy), transportation costs fell as a result of a much-expanded road network and increased trucking capacity. The national road network expanded from 26,500 kilometers in 1997 to 100,000 kilometers in 2015. Figure A.1 in the annex shows the length of roads rehabilitated from 1992 to 2011. Investment on roads was increasing throughout this period, particularly from 1995. However, road density, at 1 km per 1,000 people, is still one of the lowest in Africa. The introduction of mobile phone services

[5] PASDEP stands for Plan for Accelerated and Sustained Development to End Poverty.
[6] Less than 5 percent of cultivated land was planted with improved seeds.
[7] 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 during 2001-2005 to 18 percent during 2006-2011, and the price difference of maize from Addis Ababa to Dire Dawa (a deficit region) fell from 39 percent during 2001-2005 to 17 percent during 2006-2011.

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 phone service was 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 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 improved 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, 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 of Ethiopia. It accounted for 1% of the GDP in 2010/11, and it is one of the largest safety net programs in Sub-Saharan Africa. The immediate direct effect of transfers provided to rural households in the program 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 it may have driven 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

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. 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. This was well documented by Sen's analysis of the drought of 1973-74 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 given market are likely to be greatly dependent on local supply and demand.

The net impact of weather shocks on the price is indeterminate as it reduces both demand and supply. Thus, in a reduced form regression of the price impact of weather shocks, the coefficient on weather shock depends on the relative magnitude of supply and demand side effects of the shock. In this study, we focus on staple crops, and we may expect demand to be relatively inelastic to income in this case. As a result, we can expect to find that prices increase in response to a drought as the supply effect dominates, but this is something we test in the analysis. The pattern may differ across crops depending on their elasticity of demand. For example, the increase could be more muted for teff, which has a high elasticity compared to sorghum and maize (Tafere *et al.*, 2010).

When markets are not autarkic, trade is possible, and hence 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 in market *i*. 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 supply other markets with grain from market *i*, reducing supply and increasing the price in market *i*. Local supply and demand conditions determine prices within a band (the size of which is determined by the cost of trading between market *i* and *j*). Outside this band, prices are determined by prices prevailing in other markets.

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.

With this in mind, we present four questions that we explore using a unique data set on weather shocks and prices in rural markets across Ethiopia from 1996 to 2012. The data set combines monthly retail price data for six grains collected from 82 rural markets with data on rainfall losses in the rural district surrounding the market.[8] In addition, data on participation of the district in a rural safety net program that started in 2005, and on market access in 2000, 2005 and 2011 are also included.

Question 1: Is there an inflationary impact of weather shocks on grain prices, and when in the season is it largest?

The impact of weather shocks on supply and demand is unlikely to be uniform across the season. Most of the concern is around higher prices occurring during the lean season, but if prices increase earlier in the season the impacts of rainfall shortfalls may be felt by households much earlier than expected. The demand effect may not be observed immediately, unless households immediately adjust their consumption in response to 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. Additionally, in a market where there is poor connectivity to other markets, the supply effect may be particularly pronounced early on, until other markets start supplying the deficit market.

[8] Specifically, the percentage of crop yield calculated to be lost in the woreda due to rainfall shortfalls. A detailed discussion on how the rainfall losses are estimated is presented in the 'Data Section'.

The average impact of weather shocks on prices across markets in Ethiopia, then, 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:

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

where W_{it} is the weather shock experienced in the district surrounding market *i* in year *t*. P_{itm} is the price prevailing in market i during year t and month m. I_m is an indicator variable for month m, α_i are district fixed effects, which capture all time-invariant district specific determinants of prices, β_t are year fixed effects, which capture time-varying determinants of prices and ε_{itm} are other time-varying, location-specific shocks to prices. To account for a potential serial correlation between price series within a year and spatial correlation for observations from a market, we allow the errors to be clustered across market and year.[9] The coefficients γ_m capture the monthly impact of rainfall loss on prices. Specifically, it is the percentage increase in grain prices in month *m* as a result of a one percent point increase in rainfall loss during harvest year corresponding to that month.[10]

Question 2: Has the impact of weather shocks on grain prices fallen over time?

As documented in section 2, 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 impact on local prices. We would thus expect that the impact of weather shocks on local prices to fall over time. We test this by splitting the time period of analysis into two and estimating:

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

We would expect γ_m^2 to be closer to zero than γ_m^1. We test this by comparing 1997-2004 to 2005-2012.

Question 3: Has the impact of weather shocks on grain prices fallen more significantly in markets that have become more accessible or markets that have introduced cash transfers?

The drivers of market integration have not been uniformly present across Ethiopia. Improvements in access to markets and access to urban demand has been particularly faster in some parts of the

[9] In some specifications, data for multiple crops are combined in a single regression. For such cases, we introduce crop index (c) as follows: $P_{itmc} = \sum_{m=1}^{12}(\gamma_m^1 W_{it<2004} * I_m + \gamma_m^2 W_{it\geq 2005} * I_m + I_m) + \alpha_i + \beta_t + \varepsilon_{itmc}$. Whenever data on more than one crop are pooled together in a single estimation, we allow clustering by market, crop and year.

[10] Throughout the paper, we present an alternative specification that replaces the monthly dummies with a polynomial regression on time elapsed since harvest as follows:

$$P_{itm} = \sum_{k=1}^{3}(\delta_k W_{it} * L^k + L^k) + \alpha_i + \beta_t + \varepsilon_{itm}$$

where *L* indicates the time elapsed since harvest is collected in October, and it runs from 1 to 12 during November-October. To reconstruct the monthly impacts, as in the 12-month dummies represented by I_m in equation 1, we use the estimated coefficients ($\delta_1 - \delta_3$) and corresponding elapsed time, i.e. L, L^2 and L^3. In other words, the impact in each month (γ_m) is calculated as: $\sum_{k=1}^{3} \delta_k * L^k$, where *L* ranges from 1 for November to 12 for October.

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.

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 be scaled up when the weather is bad. Some districts have received transfers in kind and some in cash. The in-kind transfers from PSNP affect both the local demand and supply of food, but cash transfers have no supply effect, only a demand effect. We examine whether the impact of weather on local prices is smaller in places where the PSNP has been introduced. We examine whether the presence of cash transfers made as part of the PSNP has been associated with a lower demand effect of weather on prices in markets of the recipient districts, causing the inflationary supply effects to dominate in these markets.

Districts are not selected to receive transfers at random. The PSNP has been targeted to more food-insecure *woredas*/districts in Ethiopia.[11] Weather shocks may have had a differential impact on prices in these markets even before the PSNP transfers were introduced in 2005. 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, requires that there were no other reasons for the relationship between weather shocks and prices to be changing differently in PSNP districts, and this is not something we can assume. The results of this analysis cannot determine whether it is the introduction of the safety net that has driven any observed changes.

Question 4: Do weather shocks impact local wages for unskilled labor?

In addition, we examine whether the wage data recorded for unskilled workers in the monthly retail market survey indicates weather shocks having an impact on local labor markets. In some contexts, the negative shock to farm incomes that a weather shock 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 where farms and small business rely on family labor, we may expect both effects to be small. Therefore, we anticipate the negative effect on wages to be negligible in rural Ethiopia, contrary

[11] Administratively, Ethiopia is divided into nine regions/*kilils* (Tigray, Afar, Amahara, Oromia, Benishangul-Gumuz, Gambella, Harari, Somali and Southern Nations, Nationalities, and Peoples' Region (SNNP)) and two autonomous cities (Addis Abeba and Dire Dawa). These regions and cities are divided into *zones* or sub-cities, which are further divided into districts (*woredas*).

to wage depressing effects in India documented by Jayachandran (2006). This question is explored by estimating:

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

where $wage_{it}$ represents wages in market i in year t and month m.

4. Data

In this study, we match data on monthly retail prices of six major cereals (teff, wheat, maize, sorghum, barley, and millet) and wages of unskilled workers in 82 markets from 1997 to 2013 with annual weather shock data for the same period. In addition, the price and weather information is combined with data on the type of PSNP transfers households in the beneficiary districts since 2005 (if any) and data on access to towns with population greater than 50,000 in 1997 and 2004. The data is introduced in section 4.1. In section 4.2, the key features of weather shocks 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.[12] The data come from the Retail Price Survey, which is conducted 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 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 that were 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 in districts which experience only one major rainy season, *Meher* season. This is done by excluding markets that also experience another rainy season, *Belg*. We use nominal prices in the analysis and include year and monthly dummies to control for inflation and seasonal price patterns.[13]

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.

We use a weighted average of the rainfall during the growing season for the analysis. The relevant rainfall measure for this analysis is not necessarily the total rainfall that falls in the season as the timing of the rainfall also matters for crop production. In order to aggregate decadal rainfall data into one number which accurately reflects both the quantity and the timing of the rainfall experienced in the district in that season, we use a crop model, chosen based on the crops usually grown in a given place. The crop model measures how sensitive the crop is to rainfall losses at that moment in the production cycle. Rainfall losses in that 10-day period are given more weight. The

[12] Occasionally there were months in which prices of certain commodities were not collected on certain markets. This data is treated as missing.

[13] Specifically, the prices are expressed in log of Ethiopian birr per kilogram, and birr per day for wages.

crop model also takes into account the amount of evapotranspiration normally recorded at that location. The final weighted average of rainfall losses reflects the proportion of normal yield that is estimated to have been lost during that season due to poor rainfall in that location. It is important to note that this is a calculation, though, not an estimate from a regression.

The LEAP loss estimates are compiled for each year since 1996. Rainfall losses are produced for both the main *Meher* season as well as the secondary *Belg* season in the parts of the country that experience this second season. Planting and harvesting dates for each season vary across 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) also show that the rainfall-based yield loss estimates from LEAP are highly predictive of yields measured in the CSA's yield estimates using crop cutting and harvesting experiments.

Roads: We use Schmidt and Kedir's (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 to provide a district level average estimate.

Agricultural production practices: We use *zone* level measures of increases in the proportion of farmers that have reported applying fertilizer from 1997 to 2011. These measures are compiled using the annual Agricultural Sample Survey conducted by CSA.

*PSNP***:** 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 have been quite stable since the program was started in 2005.[14] 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 received. The transfer that each *woreda* receives is either cash only or a combination of cash and food. Based on this review, *woredas* were classified into three groups: those that are not in the PSNP, those that receive only cash and those that receive both cash and food under the PSNP. We use these categories in the analysis.

4.2. Weather shocks across time and space

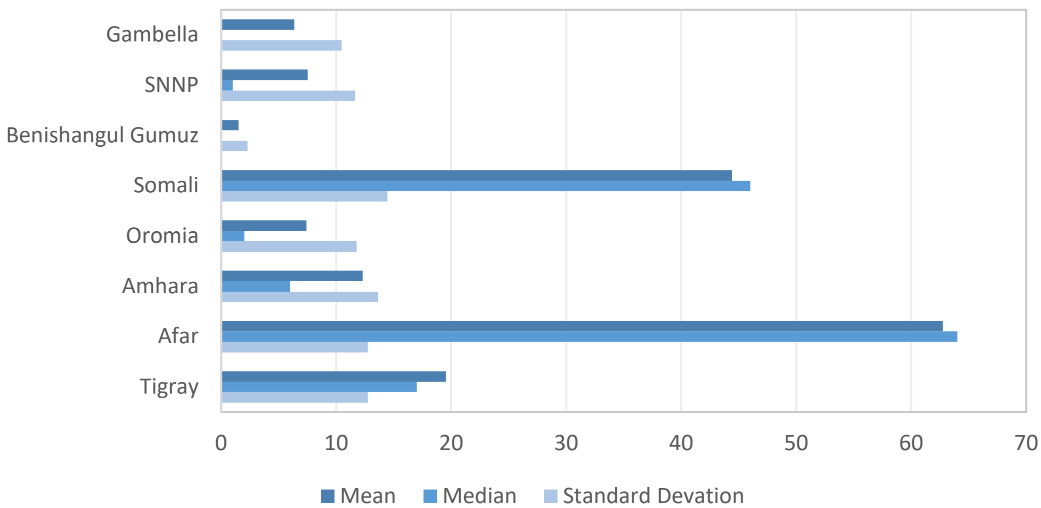
In this section we provide a brief description of the extent of rainfall losses in Ethiopia and how these losses vary temporally and spatially. We also describe the trend in grain prices across regions.

Figure 1 presents the mean, median and standard deviation of rainfall losses during the main *Meher* season in 8 regions over 17 years from 1996 to 2012. There is a substantial regional heterogeneity in the amount rainfall lost. For instance, Afar and Somali regions experience very high rainfall losses on average, and they respectively lose about 60 and 42 percent of their *Meher* rainfall during this period. On the other hand, Benishangul-Gumuz, SNNP, and Gambela regions experience low levels of rainfall loss. Despite this variation in the amount of rainfall lost on

[14] The number of beneficiaries *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).

average across regions, the standard deviation of rainfall losses is quite constant across regions (with the exception of Benishangul-Gumuz which experiences very low levels of variation). This suggests that although rainfall losses are often high on average in Afar and Somali regions, they are not more variable than in other regions.

Figure 1: Meher rainfall losses across regions during 1997-2012 period



Note: the rainfall loss is measured in terms of the amount of yield that is calculated to have been lost as a result of rainfall shortfalls during the season. Source: LEAP from 1997 to 2012

To explore the temporal variation in rainfall losses in the country, we present annual average and standard deviation of rainfall losses from 1996 to 2012 (Figure A.2 in the Annex). There is a considerable year-to-year variation in rainfall losses. Some years particularly standout as ones in which bad droughts were experienced: 1999-2003, 2008, and 2012. The share of *Meher* rainfall lost was the highest in 2001, and the mean rainfall loss in the country was 18 percent. Another notable result is that the spatial variation in rainfall losses tends to increase in drought years. This evidence suggests that rainfall 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 agroclimatic conditions in different parts of Ethiopia. These spatial differences are leveraged to study the effects of localized weather shocks on grain prices.

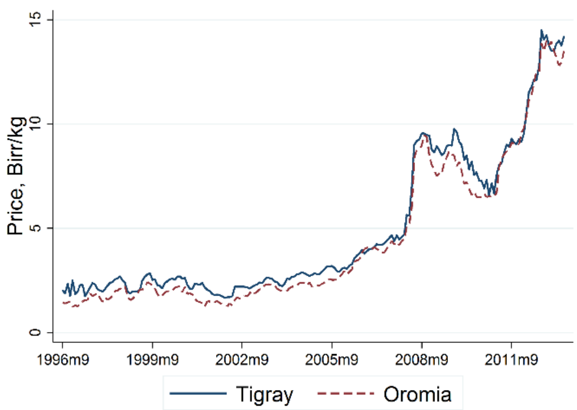
There are also major year-to-year variations in rainfall losses in each region. Figure A.3 shows the average rainfall losses in each region from 1996 to 2012. In almost all regions, 2001 has been the year when the highest rainfall loss was experienced. For instance, in Afar and Somali regions in 2001 it was calculated that they would lose more than three-quarters and half of their yields as a result of poor rainfall. Afar and Somali regions also had the highest rainfall losses in each year.

4.3. Price trends

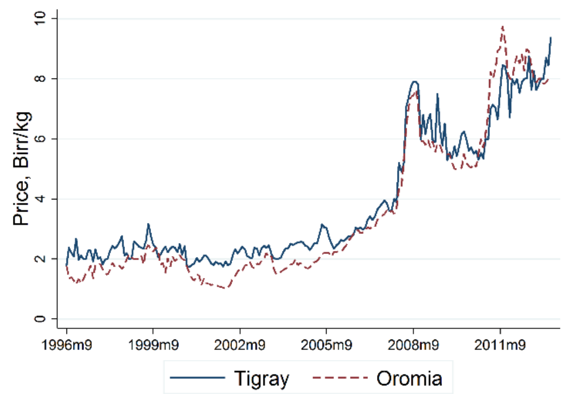
Nominal price trends for the three most commonly traded commodities—mixed teff, white wheat and maize—for Tigray and Oromia are presented in Figure 2 (prices are averaged across markets in each of these regions). The figures show that grain prices were quite stable until 2007 and they spiked during the 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 2: Trends of nominal prices for commonly traded cereals

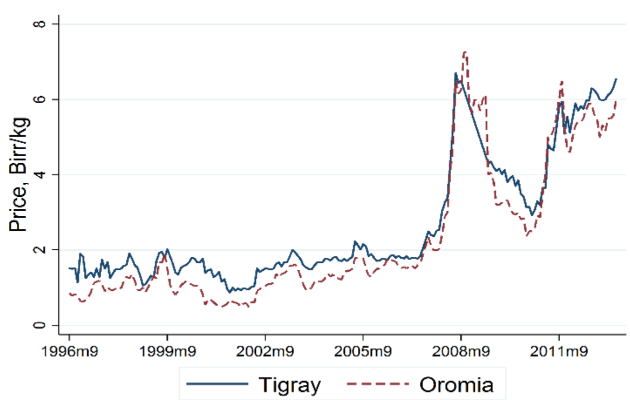
a. Mixed Teff



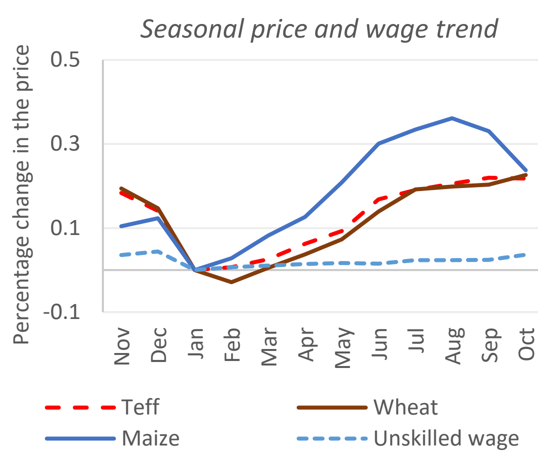
b. White Wheat



c. Maize



d. Seasonality



Prices experience considerable seasonality. Figure 2d 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 all 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

The impact of rainfall losses on monthly prices is presented in Figure 3 (results from estimating equation 1).[15] 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. Market fixed effects are also included to control for the susceptibility of the local market to the shock (Dell *et al.*, 2014) and other unobserved time-invariant market characteristics. The year fixed effects control for inflation.[16] We also allow clustering of standard errors across markets, years and months. For regressions that pool prices across crops, clustering is also allowed across crops. The impact is estimated for each month following the *Meher* season harvest from November to October the following year.

The results show that there is seasonality in the impact of rainfall losses on prices. In the harvest period from November to December, the impact of the weather on price is muted. Prices start to increase, but only marginally. The impact of rainfall losses on prices can be contextualized by considering a moderate, 1 in 5-year drought that causes a 30 percent loss in rainfall. This type of moderate drought would increase prices by 3 percent in December. The main impact on prices is observed by the end of harvest in January and lasts for 4 months until April. In this period a moderate drought results in a 9 percent increase in prices. The price impact lessens from May until the following harvest and is already back to 3 percent by the beginning of the lean season in July.

These three findings—the limited price effect until the full harvest is complete, the sudden increase in prices on completion of harvest, and the decline in prices by the start of the lean season—are not necessarily expected. Information about the harvest is available well before January as rainfall conditions are known and early harvests are observed, so it is not clear why there is a sudden jump in prices upon completion of harvest and before any shortages in local markets occur. The gradual dissipation of the price impact from May could reflect lower incomes driving lower demand or increased supply from other markets. This could perhaps be expected, but it is important to note that it is contrary to the received wisdom that price inflation following a

[15] Note that harvest is usually collected starting from November. Therefore, rainfall losses from the previous planting season are matched with prices starting from the harvest month till the next harvest is collected.
[16] As a robustness check, real prices are used as the dependent variable, using monthly national CPI to deflate prices. The results are not qualitatively different. They are excluded for brevity.

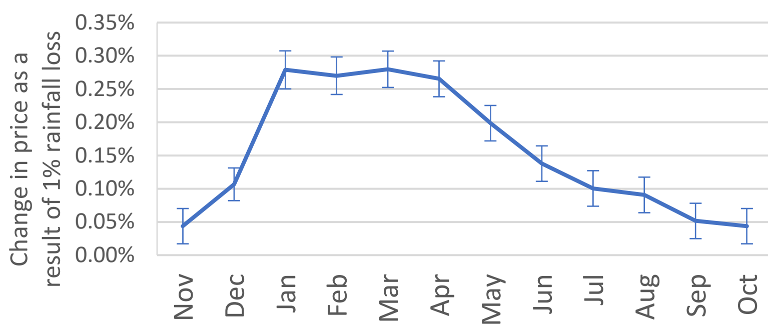
poor harvest is particularly challenging during the lean season. This analysis shows that food price inflation during the lean season is not much higher after a poor harvest than in a regular year.

These results can be summarized in a polynomial regression with the elapsed time since the harvest is collected in November, column 2 of Table 1. The polynomial approximation reflects the monthly relationship well in each case. So, for the rest of the paper, this is the empirical specification used.

In Figure 4 the results are presented separately for areas in which there is only one *Meher* harvest and areas in which there is both a *Meher* harvest and a minor *Belg* harvest (Figures 4a-b). In areas without a *Belg* harvest the inflationary impact of drought remains higher from May to October, suggesting some of the dissipation is due to the supply effect, but not all (Figure 4a).

Figure 4 also presents results separately for the three grains for which price data is most commonly collected: mixed teff, white wheat and maize (Figures 4c-h respectively). These figures show that the price pattern is consistent 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, that is why the impact of the drought on prices is already strong by November and there is reversion to the mean in September to October.

Figure 3: 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 rainfall loss is the percentage of crop yield calculated to be lost due to rainfall shortage.

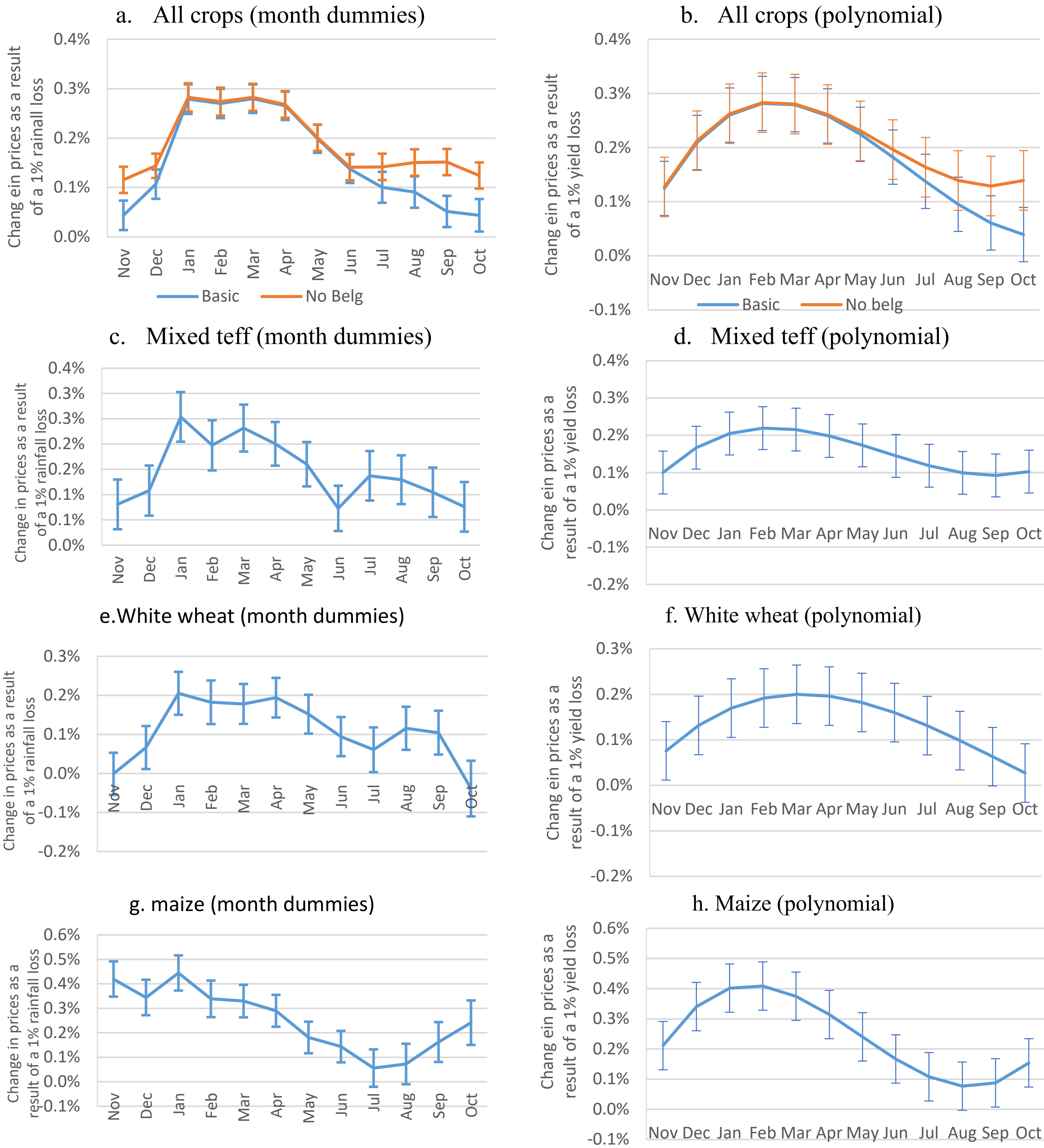
Table 1: The average impact of weather shocks on grain prices, 1997-2013

	Impact on ln(price)	P-value	Impact on ln(price)	P-value
Percent rainfall loss				
November	0.0011***	0.00		
December	0.0013***	0.00		
January	0.0028***	0.00		
February	0.0027***	0.00		
March	0.0028***	0.00		
April	0.0027***	0.00		
May	0.0020***	0.00		

June	0.0014***	0.00		
July	0.0010***	0.00		
August	0.0009***	0.00		
September	0.0005*	0.05		
October	0.0004	0.10		
No. of Months after October (t)			0.0015***	0.000
t^2			-0.0002***	0.000
t^3			0.0000***	0.000
N	126,306		126,306	
Number of markets	82		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. Standard errors are cluster at market, year and crop level.

Figure 4: The impact of weather shocks disaggregated by season and grain type



Note: Prices are the log of the nominal price in Ethiopian Birr per kg and rainfall loss is the percentage of crop yield calculated to be lost due to rainfall shortage. The regressions behind these figures control for all the covariates listed in Table 1. We allow clustering of errors at market and year level for sub-figures c-h as well as at crop level (for sub-figures a-b).

In contrast, there is little significant impact of weather shocks on unskilled wages. The impact of weather shocks on unskilled wages is depicted in Table 2. The coefficients are significant in only four months and remain very small. This weak impact of drought on wages might be due to the limited hired labor in rural Ethiopia. Farms typically rely on family labor, and there are initially few employment opportunities outside the farm.[17] This is in contrast to findings for rural India where agricultural wage labor is a much more important source of employment for rural landless households (Jayachandran 2006).

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

	Impact of 1 percent of rainfall loss on ln(daily wage) of unskilled labor in the following months	
	Coefficient	P-value
November	0.000*	0.09
December	0.000	0.17
January	0.001*	0.06
February	0.001*	0.08
March	0.000	0.18
April	0.000	0.11
May	0.000	0.15
June	0.001	0.10
July	0.000	0.36
August	0.000	0.43
September	0.001*	0.08
October	0.000	0.31
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. We allow clustering of standard errors at market and year level.

Thus far, we have presented the average impact of weather shocks on prices across the 82 markets over the entire study period. 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 fully informative. 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.

To check this, we compare 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

[17] This result does not change when looking at the impact on different periods of time. It does not change when considering real wages either.

markets by the poverty rate of the surrounding zone. The results indicate that weather shocks have a more inflationary effect in the average market than in markets in the poorest pars of the country.[18] 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, which are 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.

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 17-year period from 1997 to 2013. However, as described above this has been a period of considerable changes in Ethiopia and it may be that the impact of local weather shocks on local prices is very different at the end of this period than at the beginning. 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. We examine whether the impact of drought on prices has changed over time by estimating equation 2. Figure 5a shows the impact of weather shocks on grain prices before and after 2005. We choose this cutoff because it falls midway in the time period we are considering and there was a noticeable difference in infrastructure and safety net investments before and after 2005.

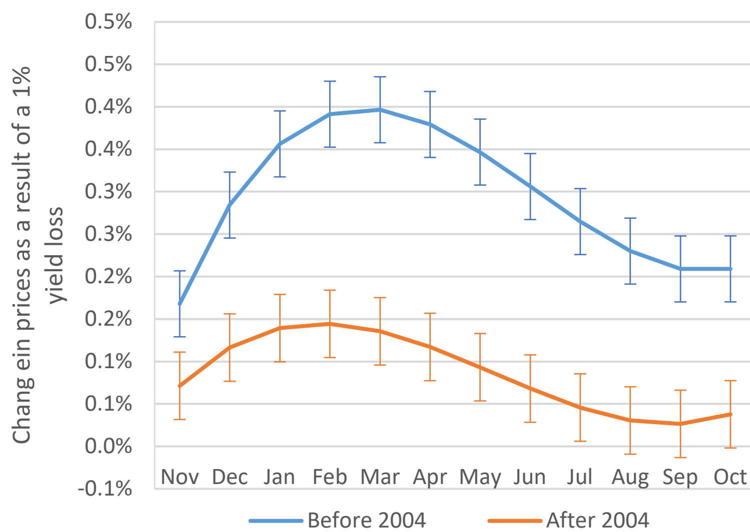
Over time the impact of weather shocks on prices has fallen. On average, a moderate drought would have induced a 12 percent increase in prices in March before 2004 in comparison to a 4 percent increase post 2004. After 2004 there was no inflationary impact of drought shocks on prices during much of the lean season, quite in contrast to the prevailing narrative of lean season food price inflation following a drought. The reduction in the impacts of drought on prices seemed to occur largely after 2002.[19]

We test whether these results are due to one specific year, for example if the years of drought that we cover before and after 2004 were sufficiently different to be driving the results. We test this by excluding one year at a time and testing whether or not the same relationship is observed. The results are presented in Figure A.4 and show that the findings are robust to the

[18] The graphs are redacted for brevity.
[19] The results for individual crops show the same pattern, largely insignificant impact of drought on prices after 2007. The results are redacted to save space.

exclusion of any one year, suggesting this change represents a shift in how rainfall shocks are impacting drought rather than reflecting the nature of any one drought.

Figure 5: 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 rainfall loss is the percentage of crop yield calculated to be lost due to rainfall shortage.

We examine whether the change in the impact of rainfall shocks on food prices over time is correlated with some of the major government policies introduced during this period. We examine investments in roads and the introduction of a large safety net program, the PSNP. 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 larger reductions in weather-induced price volatility. It could also have been the case that the introduction of the PSNP reduced the impact of weather shocks on grain prices by providing an alternate source of income and in some communities, also food supplies (in some locations beneficiary payments are made in food).

Both infrastructure investments and the PSNP are targeted investments, and areas with these interventions are different from other districts. We cannot test whether higher road investment or the introduction of the PSNP had an impact, but we examine if trends were different between these districts. The regression results are presented in Figure 6. Panel a shows the estimated price impact for four types of districts: those that had neither PSNP or high road investment, those that had either the PSNP or high road investment, and those that had both the PSNP and high road investment. It shows the estimated price impact before and after 2005 for these four groups. Panel b shows the difference in the price impact before and after 2005 for these four groups. Again, 2005 is chosen because this is when the PSNP was introduced and also when infrastructure investment started to increase rapidly.

Before discussing the differences presented in panel b we note that, even prior to 2005, there was a difference in the price impacts in districts with low road investments and high road investments (panel a, comparing the green and brown bold lines to the blue and grey bold lines). Places that received more road investment already saw inflationary price impacts dissipating much more quickly before 2005. It is not clear why this is the case. One explanation is that road investment was targeted to better connected areas and better-connected areas are less likely to be impacted by low supply.

Secondly, we note that in places that have had high road investments there is very little inflationary impact of rainfall losses post 2005. This is true regardless of whether or not the PSNP is operational in the district. We cannot point to road investments as causing this pattern, but the results do show that there are some places in Ethiopia where local weather shocks have no meaningful impact on prices. This is quite encouraging, suggesting that price shocks are not an automatic feature of drought in low income countries.

Panel b shows that the largest reductions in inflationary impacts of drought occurred in places that received both the PSNP and high road investments after 2005. The smallest reductions occurred in places that had neither the PSNP nor high road investments. Those receiving one lie in the middle. We cannot say why we observe this difference.

In some districts the PSNP was introduced through cash payments to beneficiaries and in other districts, it was introduced in the form of food aid. It is possible that these two types of payment method have very different implications for the relationship between rainfall shocks and food prices. Cash payments increase demand for food without impacting supply, while food aid payments increase both the demand for food and the supply of food. Cash payments could have more inflationary impacts in local markets than food payments.

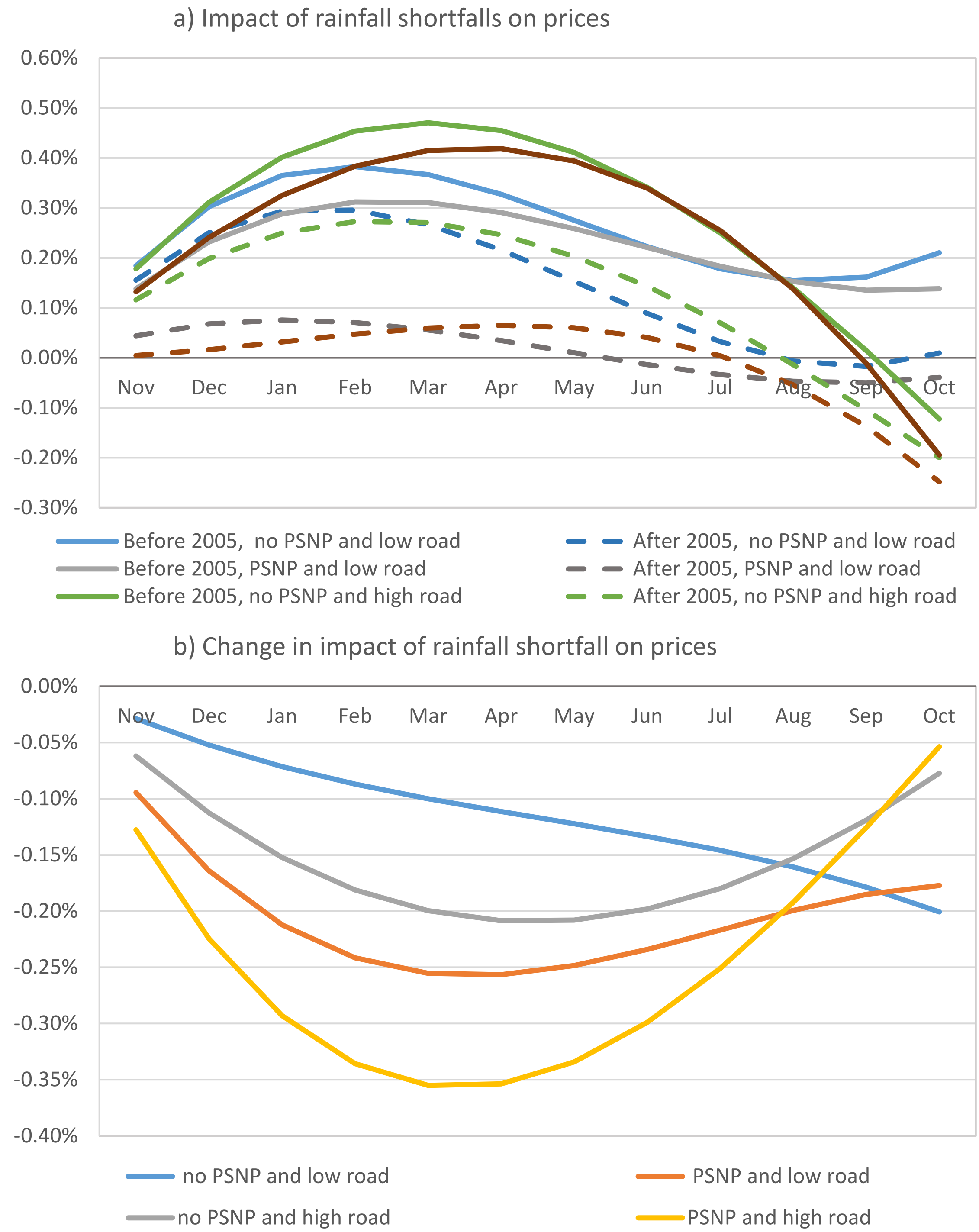
We examine whether there was a different relationship between drought and types of transfer under PSNP in Table 3. The results show that food transfers were more likely to be provided in places where the inflationary effects of food aid were larger, and this relationship was reversed after 2005. There is no difference in the impact of rainfall shocks on prices in the PSNP cash districts either before or after 2005. The results are consistent with food payments being well-geographically targeted to areas with higher food price inflation but this pattern changing significantly after 2005 (as a result of the provision of food in the PSNP or something else, we cannot say). The results are also consistent with cash payments having no inflationary effect in places where they are provided.

Table 4 The impact of weather shocks on grain prices in places with high road investment and PSNP

	Impact on ln(price)	p-value
Percent rainfall loss interacted with		
No. of Months after October (t)	0.002***	0.00
t^2	-0.000***	0.00
t^3	0.000***	0.00
After 2005 * t	-0.000	0.39
After 2005 * t^2	0.000	0.79
After 2005 * t^3	-0.000	0.83
High roads * t	-0.000	0.63
High roads * t^2	0.000**	0.02
High roads * t^3	-0.000***	0.00
High roads after 2005 * t	-0.000	0.32
High roads after 2005 * t^2	0.000	0.69
High roads after 2005 * t^3	0.000	0.91
PSNP district * t	-0.001*	0.07
PSNP district * t^2	0.000**	0.03
PSNP district * t^3	-0.000**	0.03
PSNP district after 2005 * t	-0.001**	0.03
PSNP district after 2005 * t^2	0.000	0.11
PSNP district after 2005 * t^3	-0.000	0.31
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 time since harvest 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. Standard errors are cluster at market, year and crop level.

Figure 6: Impact of rainfall on prices in places with high road investment and the PSNP



Note: estimates using results from Table 4. See footnote to table 4 for details on the estimation.

Table 3 Food versus cash transfers in the PSNP

	Impact on ln(price)	p-value

Percent rainfall loss interacted with		
No. of Months after October (t)	0.0014***	0.00
t^2	-0.0002***	0.00
t^3	0.0000*	0.06
After 2005 * t	0.0005	0.38
After 2005 * t^2	-0.0001	0.23
After 2005 * t^3	0.0000	0.21
High roads * t	0.0002	0.52
High roads * t^2	0.0001	0.31
High roads * t^3	-0.0000**	0.02
High roads after 2005 * t	-0.0011***	0.01
High roads after 2005 * t^2	0.0002*	0.07
High roads after 2005 * t^3	-0.0000	0.25
Cash PSNP district * t	-0.0006	0.15
Cash PSNP district * t^2	0.0001	0.15
Cash PSNP district * t^3	-0.0000	0.21
Cash PSNP district after 2005 * t	-0.0004	0.50
Cash PSNP district after 2005 * t^2	0.0001	0.62
Cash PSNP district after 2005 * t^3	-0.0000	0.66
Food PSNP district * t	0.0008**	0.03
Food PSNP district * t^2	-0.0002**	0.04
Food PSNP district * t^3	0.0000**	0.05
Food PSNP district after 2005 * t	-0.0016***	0.00
Food PSNP district after 2005 * t^2	0.0003***	0.01
Food PSNP district after 2005 * t^3	-0.0000**	0.02
N	126,306	
Number of markets	82	

Note: *** indicates significant at 1%, ** significant at 5% and * significant at 10%. The regression includes time since harvest (t, t^2 and t^3) and year, grain type (by grade) and market fixed effects. Robust standard errors were used to estimate the p-values presented. We allowed for autocorrelation within each panel while allowing the coefficient of AR(1) process to vary across panels.

6. 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 key meso-level effects of localized weather shocks on grain prices and wages, which in turn affect welfare. Further, the study examines when these meso-level effects are observed, providing an understanding of the timing of the impact of drought on welfare.

The results show that there is clear seasonality in the impact of weather shocks on grain prices. In contrast, weather shocks have no effects on unskilled wages. A moderate, one in five-year drought, causes a 9 percent increase in grain prices immediately on completion of the harvest, but by six months after harvest this effect diminishes significantly. 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. Or supply effects could weaken as additional supply becomes available. Regardless of the reason, the immediate impact of the drought on prices shows the importance of acting quickly after a drought when markets are not well integrated in order to prevent the inflationary effects from impacting welfare.

As Ethiopia has developed over this period, the impact of local weather shocks on local prices has attenuated. A moderate drought would have resulted to price increases of 12 percent in the first half of the period considered, but that fell to 4 percent by the latter half of the period. In some parts of Ethiopia (those places where road investments have been high) there is almost no inflationary impact of local drought on prices, which is very encouraging. 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. We would have expected larger impacts in places with higher road investments, but the results are consistent with other work on Ethiopia that shows reductions in transaction costs because of other factors such as improved trucking capacity and the introduction of cell phones (Minten *et al*., 2014).

The time-trends in the impact of drought on prices also cannot be explained fully by the introduction of the PSNP. Food transfers in the PSNP were introduced in places where the impact of drought was more inflationary. These are also the places where reductions in the inflationary impacts of rainfall shortfalls were the largest, but it is not clear that this is a result of the PSNP.

A comparison of PSNP districts receiving food and cash transfers suggests there is no evidence that cash transfers are having untoward effects on prices during times of drought. This is important information for policy makers when considering types of transfers to be provided to 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.

References

Aker, Jenny. (2008) "Rainfall Shocks, Markets, and Food Crises: Evidence from the Sahel", Center for Global Development, Working Paper Number 157

Aker, Jenny. 2010. "Rainfall Shocks, Markets and Food Crises: The Effect of Drought on Grain Markets in Niger." Working Paper.

Bachewe, F, G Berhane, B Minten, and A.S. Taffesse. 2015. "Agricultural Growth in Ethiopia (2004-2014): Evidence and Drivers." International Food Policy Research Institute (IFPRI) Ethiopia Strategy Support Program (ESSP).

Baffes, John, Varun Kshirsagar, and Donald Mitchell. 2015. What Drives Local Food Prices? Evidence from the Tanzanian Maize Market. Policy Research Working Papers 7338. The World Bank.

Brown, Molly E., and Varun Kshirsagar. 2015. "Weather and International Price Shocks on Food Prices in the Developing World." Global Environmental Change 35: 31–40.

Burgess, Robin, and Dave Donaldson. 2010. "Can Openness Mitigate the Effects of Weather Shocks? Evidence from India's Famine Era." American Economic Review 100 (2): 449–53.

Carter, Michael R., Peter D. Little, Tewodaj Mogues, and Workneh Negatu. 2007. "Poverty Traps and Natural Disasters in Ethiopia and Honduras." World Development 35 (5): 835–56.

Clarke, D. and Hill. R.V., 2013. Cost-Benefit Analysis of the African Risk Capacity Facility. IFPRI Discussion Paper 1290

Conway, Declan, and E. Lisa F. Schipper. 2011. "Adaptation to Climate Change in Africa: Challenges and Opportunities Identified from Ethiopia." Global Environmental Change 21 (1): 227–37.

Dell, M., Jones, B. F., & Olken, B. A. (2014). *What do we learn from the weather? The new climate-economy literature.* Journal of Economic Literature, 52(3), 740–798.

Demeke, Abera Birhanu, Alwin Keil, and Manfred Zeller. 2011. "Using Panel Data to Estimate the Effect of Rainfall Shocks on Smallholders Food Security and Vulnerability in Rural Ethiopia." Climatic Change 108 (1-2): 185–206.

Dercon, Stefan. 2004. "Growth and Shocks: Evidence from Rural Ethiopia." Journal of Development Economics 74 (2): 309–29.

Dercon, S. and C. Porter. 2014. Live Aid Revisited: Long Term Impacts of the Ethiopian Famine of 1984 on Children. Journal of the European Economic Association 12(4): 1542-4774.

Devereux, S. 2007. "The Impact of Droughts and Floods on Food Security and Policy Options to Alleviate Negative Effects." *Agricultural Economics* 37 (1): 47–58.

Durevall, Dick, Josef L. Loening, and Yohannes Ayalew Birru. 2013. "Inflation Dynamics and Food Prices in Ethiopia." Journal of Development Economics 104: 89–106.

Ethiopian Road Authority (2013), "Assessment of 15 Years Performance of Road Sector Development Program", Addis Ababa

Ferrière, Nathalie, and Akiko Suwa-Eisenmann. 2015. "Does Food Aid Disrupt Local Food Market? Evidence from Rural Ethiopia." World Development 76: 114–31.

Gabre-Madhin, E. 2001. Market Institutions, Transaction Costs and Social Capital in the Ethiopian Grain Market. IFPRI Research Report 124, Washington D.C.

Gelan, Ayele Ulfata. 2007. "Does Food Aid Have Disincentive Effects on Local Production? A General Equilibrium Perspective on Food Aid in Ethiopia." Food Policy 32 (4): 436–58.

Gilligan, D., and J. Hoddinott. 2007. "Is There Persistence in the Impact of Emergency Food Aid? Evidence on Consumption, Food Security, and Assets in Rural Ethiopia." *American Journal of Agricultural Economics* 89(2): 225–242.

Gray, Clark, and Valerie Mueller. 2012. "Drought and Population Mobility in Rural Ethiopia." World Development 40 (1): 134–45.

Hill, R. and Tsehaye, E. 2014. "Growth, safety nets and poverty: Assessing progress in Ethiopia from 1996 to 2011". Background paper prepared for the Ethiopia Poverty Assessment.

Jayachandran, S. "Selling labor low: Wage responses to productivity shocks in developing countries." Journal of political Economy 114, no. 3 (2006): 538-575.

Key, N. E. Sadoulet and A. de Janvry. 2000. "Transactions Costs and Agricultural Household Supply Response." American Journal of Agricultural Economics 82 (May 2000): 245–259

Little, Peter D., M. Priscilla Stone, Tewodaj Mogues, A. Peter Castro, and Workneh Negatu. 2006. "'Moving in Place': Drought and Poverty Dynamics in South Wollo, Ethiopia." The Journal of Development Studies 42 (2): 200–225.

Minten, Bart, David Stifel, and Seneshaw Tamru. 2014. "Structural Transformation of Cereal Markets in Ethiopia." The Journal of Development Studies 50 (5): 611–29.

MOARD. 2010. "PSNP 2003 (2010/11) Annual Plan". Ministry of Agriculture and Rural Development

Schmidt, Emily, and Mekamu Kedir. 2009. "Urbanization and Spatial Connectivity in Ethiopia: Urban Growth Analysis Using GIS." International Food Policy Research Institute (IFPRI). Addis Ababa.

Sen, A. 1981. *Poverty and Famines: An Essay on Entitlement and Deprivation*. Oxford University Press.

Sharp, K. 2006. Targeting Ethiopia's Productivity Safety Net Program (PSNP). Overseas Development Institute. London, UK

Tadesse, Getaw, and Gerald Shively. 2009. "Food Aid, Food Prices, and Producer Disincentives in Ethiopia." American Journal of Agricultural Economics 91 (4): 942–55.

Tafere, K AS Taffesse, S Tamiru, N Tefera, Z Paulos. 2010. Food demand elasticities in Ethiopia: Estimates using household income consumption expenditure (HICE) survey data. Ethiopia Strategy Support Program II Working paper 11, IFPRI, Addis Ababa.

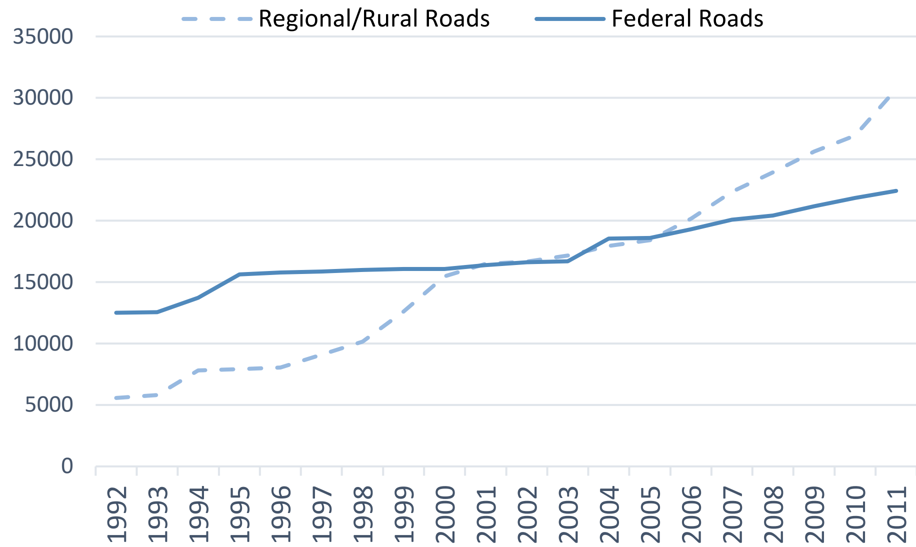
Thiede, Brian C. 2014. "Rainfall Shocks and Within-Community Wealth Inequality: Evidence from Rural Ethiopia." World Development 64: 181–93.

World Bank. 2015. Ethiopia Poverty Assessment.

World Bank. 2016. Ethiopia Systematic Country Diagnostic.

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 Rainfall Losses (*Meher* season)

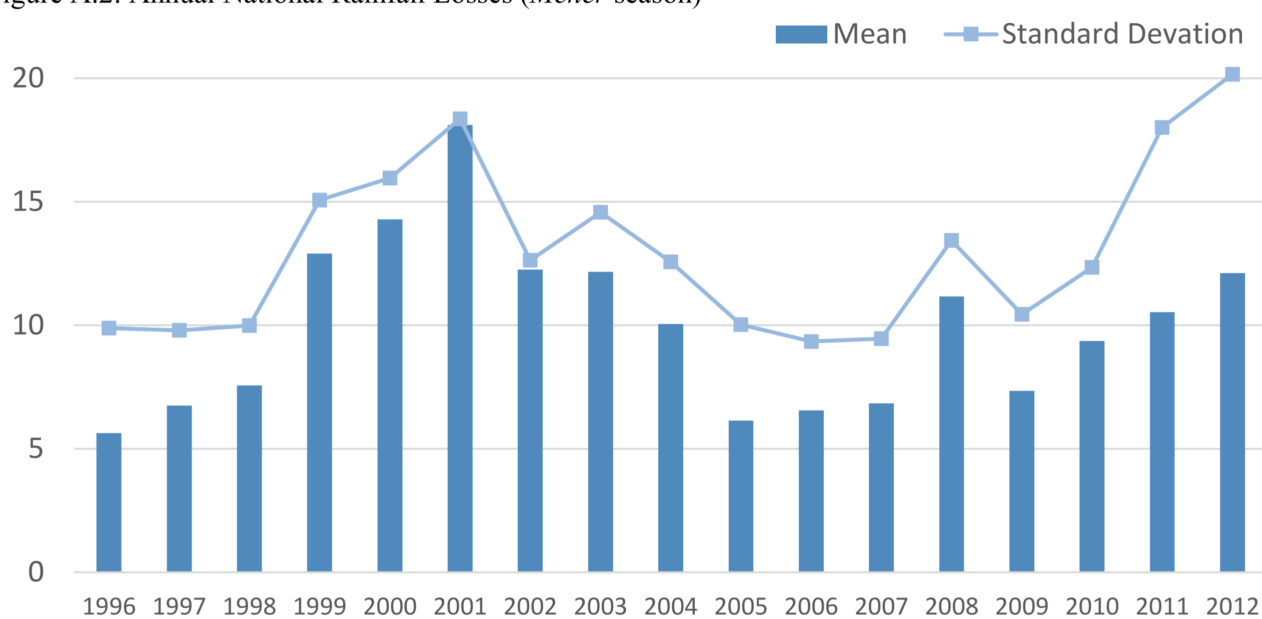
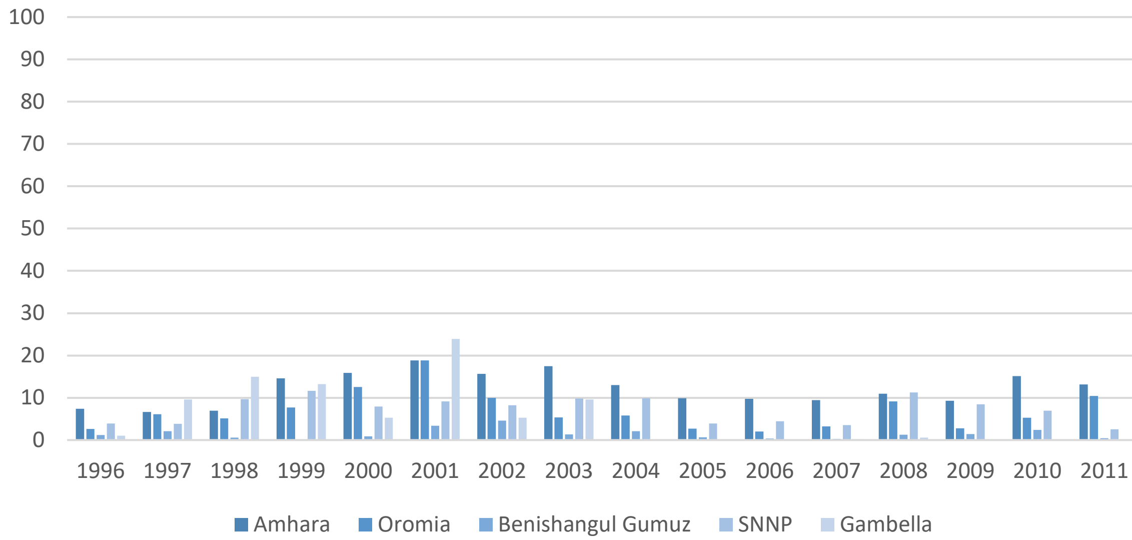


Figure A.3: Historical Average Rainfall Losses by Region (annual average for *Meher* season, 1996-2012)



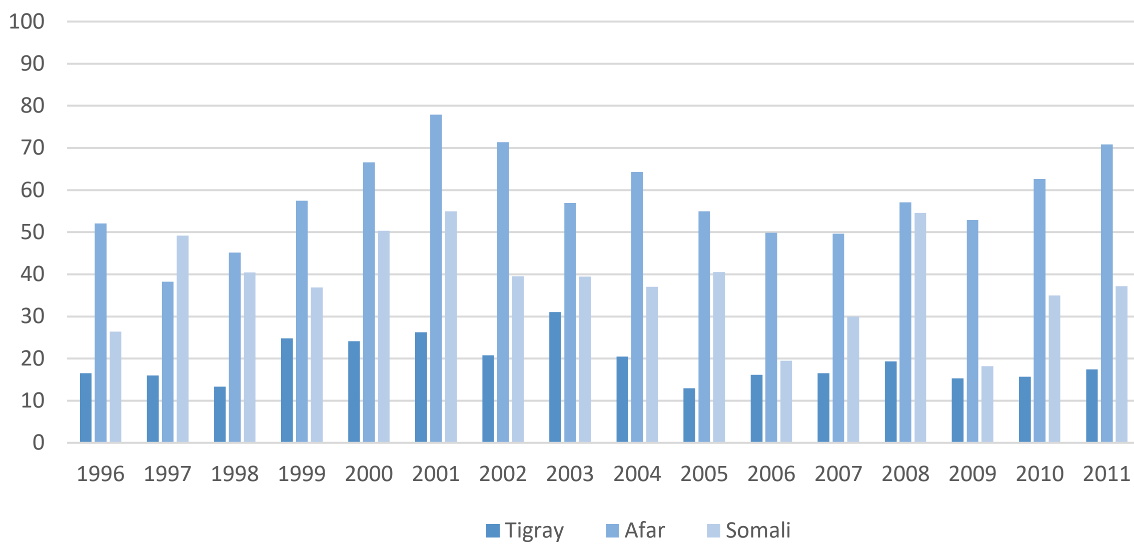
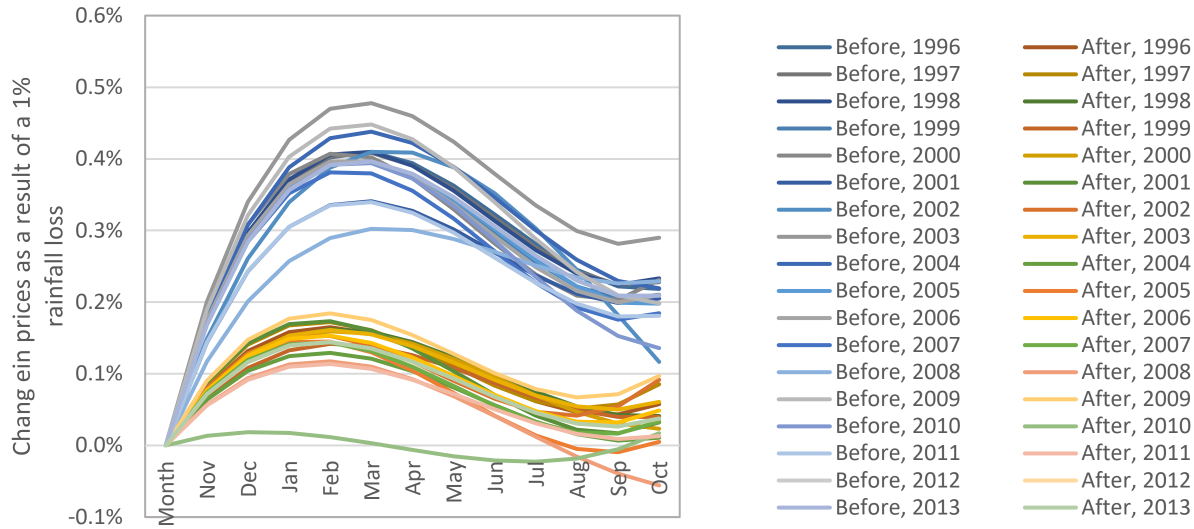


Figure A.4: The impact of weather shocks on grain prices over time



Note: Excluded years are placed after the comma. "Before" and "After stand for before 2005 and after 2005, respectively.