Fossil fuel Subsidy Reforms, Spatial Market Integration, and Welfare

Evidence from a Natural Experiment in Ethiopia

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Abstract

In light of climate change and tight fiscal conditions after the 2008 crises, fuel subsidy reform has become a popular policy. The G20 leaders, in their Pittsburgh meeting in 2009, committed to phase out inefficient fuel subsidies. However, little is known about the implications of removing subsidies on food prices and welfare. I study the welfare effects of such reforms through their impacts on the spatial dispersion of food prices using a "natural experiment" from Ethiopia. I employ time-regression discontinuity (RD) design and spatial difference-in-difference (sDID) on distance from the major national market, and a highly disaggregated monthly grain price data (1996–2013) from about 300 locations. I find that: (1) the reform substantially increased grain price dispersion; (2) there are notable spatial heterogeneities in the treatment effect; (3) even if the reform has had no impact on overall price levels, it increased cross-sectional spatial price differences; and (4) net-sellers of grain in remote districts and some urban households have experienced welfare losses, but net-buyer households in remote rural areas likely benefited due to relatively low grain prices in their districts.

Keyword: Fuel subsidy, price dispersion, RD design, sDID, welfare

JEL Code: F14, Q13, Q17, Q18, H22, H23, N7

1. Introduction

Fossil fuel subsidy is globally estimated at a staggering $775 billion per year (Bast et al., 2012) and, in the three years leading up to the October 2008 reform, Ethiopia, on its part, spent about $800 million (IMF, 2009).[1] In light of climate change and tight fiscal conditions after the 2007–2008 financial crises, fossil fuel subsidy reform has been at the forefront of governments' agendas in recent years. The G20 leaders, in their Pittsburgh meeting in 2009, declared that they are "committed to rationalize and phase out inefficient fuel subsidies" to discourage wasteful energy consumption (Washington Post, 09/25/2009). Taken at face value, removing fuel subsidies is an appealing policy measure and garners support from a number of stakeholders, including green energy advocates, the International Monetary Fund (IMF), and the governments themselves. It is considered as a low hanging fruit among measures meant to mitigate anthropogenic climate change as it could ease energy price distortion and hence facilitate adoption of cleaner energy (Bast et al., 2012; Whitley, 2013). At the same time, countries like Ethiopia, which have been experiencing persistent budget and trade deficits, find the proposition attractive since fuel subsidies are thought to be poorly targeted and arguably captured by the rich. The IMF also encourages countries to remove subsidies to keep their financial house in order (see IMF (2009), and Alleyne and Hussain (2013)).

However, there is a serious lack of rigorous research on the impact of fuel subsidy reforms on welfare, through their effects on commodity prices and their spatial dispersion. Three major channels through which higher fossil fuel prices could affect food/grain prices have been identified in the literature (Mitchell, 2008; Adam, 2011; Zhang et al., 2009; Dillon and Barrett, 2015). First, fossil fuel is used in the production of grains. Second, bio-fuel, especially from maize and soybeans, often serves as a substitute for fossil fuel. Finally, fossil energy is utilized for international and local transportation/distribution of grains. The former two channels appear to be more relevant in advanced and emerging

[1] This subsidy amounts to 1.3% of nominal GDP in the same period (2006–2008).

economies.

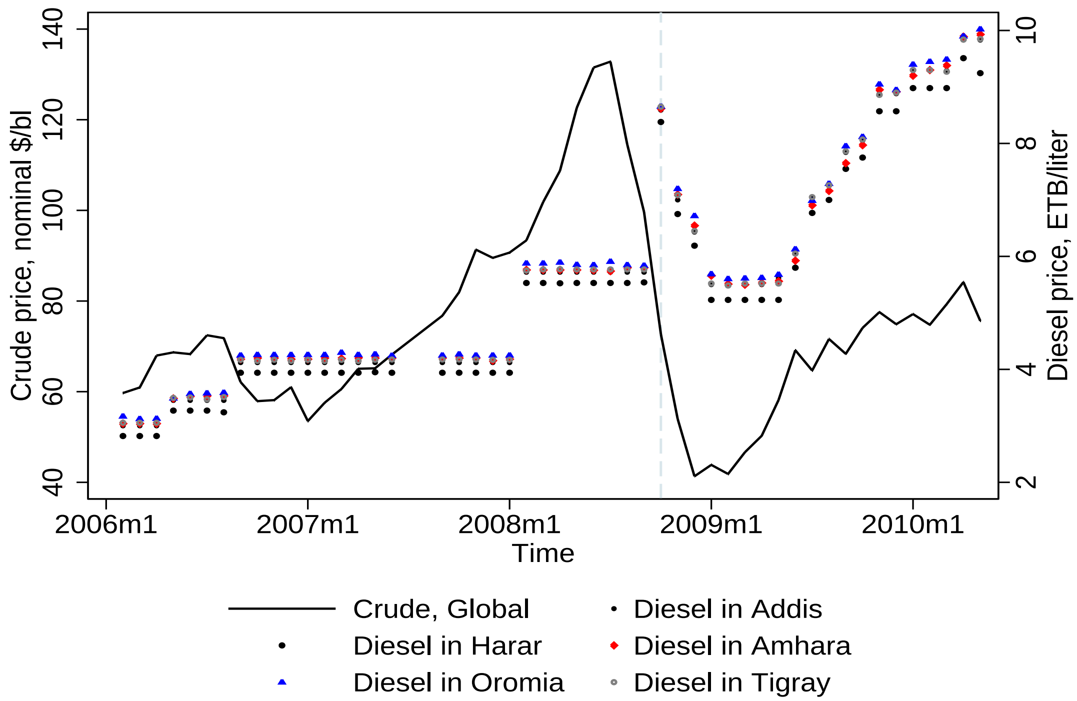
In the context of developing countries, the transportation cost channel might be more important in affecting grain prices and their spatial dispersion. For instance, Ethiopia's agriculture is characterized by smallholder, subsistence farming, with low rate of fertilizer application and limited use of machinery and irrigation. The rugged terrain and inadequate transportation infrastructure make freight cost a substantial part of the transaction cost in grain trade. Transportation of grains across long distances is typically accomplished by diesel trucks. Grain traders rely on these trucks that are hired from transport service providers, who operate in oligopolistic localized markets (see Rancourt et al. (2014) and Adam (2011))—transporting grains to urban centers and backhauling manufactured goods and agricultural inputs. As a result, transportation cost constitutes a substantial share of market values of these grains in urban centers, particularly for grains like maize and sorghum that have higher volume-to-value ratios.

To the best of my knowledge, there is no well identified study that thoroughly investigates the transportation cost channel through which fuel subsidy reforms affect food prices and hence welfare. The purpose of this study is, therefore, to investigate the effects of such reforms on spatial integration of agricultural commodity markets and hence on real incomes of net-buyers and net-sellers of grains. Clear understanding of the transmission channels in developing countries is essential for devising complementary policy measures to mitigate the negative effects of removing the subsidies. This facilitates transition into a future that is less dependent on fossil-based energy, and at the same time minimize the social welfare loss during transition.

I use a unique dataset and a "natural experiment"—a steep surge in fuel price following removal of subsidies in Ethiopia on October 4, 2008. By using detailed grain price data and household survey data, this study causally identifies the impacts of fuel subsidy reforms on agricultural commodity markets and hence welfare of grain producers and consumers. Prior to this reform, domestic fuel prices were regulated, and the Ministry of Trade and Industry (MoTI), with the approval of the Council of Ministers, has been setting fuel prices quarterly. As a result, fuel prices remained low and stable. A fuel stabilization fund was used to absorb global crude oil price shocks, and hence protected domestic consumers from oil price fluctuations. Since October 2008, the MoTI has been revising fuel prices monthly, without seeking approval from the Council of Ministers. After the reform, the country experienced unprecedented increase in the prices of petroleum products. Overnight, the prices of gasoline, diesel, fuel oil, and kerosene were increased by 6, 39, 32, and 50 percent, respectively (IMF, 2009). Figure 1 depicts the global average crude oil spot price and diesel price at the pump in different regions of Ethiopia.[2] Clearly, before the reform, diesel was cheaper relative to global crude oil price, and its price was stable. Especially during the 2007–2008 oil price shock, fuel cost remained low in Ethiopia. During the post-reform period, however, the price increased above international levels, partly to replenish the drained Oil Stabilization Fund (IMF, 2009). Since the reform, prices have been continuously revised to mimic the trend in global crude oil price.

[2]Quarterly national average retail prices of gasoline, kerosene, gas oil, and fuel oil are presented in Figure A.1, see the Annex.

Figure 1: Trends of global average crude oil price and monthly retail diesel price at the pump in different regions of Ethiopia



Data Source: Retail Price Survey, Central Statistical Authority.

Such surge in fuel prices is anticipated to have not only direct impacts on household incomes through increases in energy bills for households and businesses, but also indirect effects through increases in the price of grains and other commodities, especially in urban areas. Cognizant of the potential negative effects on the welfare of the urban poor, the government launched a food subsidy scheme targeting the poor in major urban centers.[3]

As noted above, transportation of grain from rural agricultural districts to consumers residing in urban centers is predominantly accomplished using diesel trucks. The 39% increase in diesel price could translate into higher rural-urban dispersion in agricultural

[3]One of the rationales given during the fuel subsidy reform was that the government has opted to stabilize grain prices directly (through food subsidy), and remove fuel subsidies (Carlisle, 2008)

commodity prices. Therefore, this study focuses on investigating the implications of the sharp increase in diesel price following the fuel subsidy reform on spatial dispersion of grain prices through its impact on freight cost.[4]

Time-regression discontinuity (RD) design and spatial difference-in-difference (sDID) on distance from the major national market are employed to causally attribute changes in agricultural commodity price levels and their dispersion across districts to fuel price increases as a result of the policy reform. Specifically, I implement time-RD design on a high frequency district-level price data to document any short-run, discontinuous change in price dispersion and its level around the reform time (Oct 2008). I use GIS network analysis to impute the distance of each district from Addis Abeba (aka Addis), which is the national capital and the major consumer center.[5] Spatial heterogeneity in the treatment effects (estimated using the RD-design) is investigated by comparing the treatment effects in districts at different distances from the capital. In the sDID approach, the district's distance from Addis is used as a continuous treatment variable because, holding other factors constant, the farther a district is located from the capital the impact of fuel cost on freight costs (and hence on grain price dispersion) is expected to be cumulatively higher.

The reform has increased price dispersion—absolute difference between prices in Addis and prices in other districts—for major staple grains: 'teff', wheat, maize, sorghum, and barley. The respective price dispersion for 'teff', wheat, maize, sorghum, and barley increased by 15, 7, 12, 21, and 15 percent.[6] There is also a substantial spatial

[4] The price of diesel decreased in the few months after the reform as the global crude oil price plummets. The diesel price picked up again as crude price increased after the first quarter of 2009. The identifications used in this study rely on the sharp increase in diesel price on October 4, 2008.

[5] Addis is the economic and political capital of the country. Its population dwarfs other major urban centers. In 2013, for example, its population was estimated at 3.1 million. The next nine biggest cities in the country (Mek'ele, Nazret, Dire Dawa, Gondar, Awasa, Bahir Dar, Jima, Dese, and Jijiga) had a combined population that was equivalent to 64% of Addis's population(CSA). In terms of purchasing power, Addis residents are in a better position, and they also purchase all of their grains.

[6] The increase is relative to mean prices in rural districts for the quarter prior to the reform, i.e. July-Sept 2008.

heterogeneity in treatment effects. In general, districts that are located farther from Addis experienced higher increases in price dispersion. In fact, the farther the districts are from Addis the higher the treatment effect. In effect, this confirms that the increases in price dispersion are actually driven by the higher transportation cost associated with the spike in diesel price. Even if the reform had no impact on overall price levels, it increased cross-sectional spatial price differences among the markets in the 300 districts. This confirms that, in a developing country like Ethiopia, the main transmission channel through which an increase in fuel prices is passed on to grain prices is through higher transportation cost.

The results from the spatial price analysis are used to investigate the instantaneous welfare effects of the reform. A nationally representative household survey data on households' production and consumption patterns is used to estimate the welfare losses or gains associated with the reform. The welfare effects are anticipated to be heterogeneous by location, and based on whether the household is a net-buyer or net-seller of grain as well as household characteristics such as socioeconomic status.

As expected, farm and rural households earn a higher share of their incomes from grains, and their 'spending' on grains also makes a higher share of their consumption expenditure.[7] While, non-farm and urban households earn a smaller share of their incomes from grains and expenditure on grains makes a smaller share of their expenditure, especially for the non-poor. Therefore, the dampening of grain prices in remote rural areas following the removal of the fuel subsidy has resulted in higher income losses among farm households in these districts. Net-seller farm households in high agricultural potential rural areas, where relative prices have decreased, and net-buyer urban residents, who have faced higher grain prices, are likely to have experienced decreases in real incomes due to the reform. Whereas, net-sellers in low agricultural potential rural areas that have experienced surge in relative prices, and net-buyer

[7] 'Spending' on grains also includes imputed values of own consumption.

households in high agricultural potential remote areas could have experienced welfare gains. In addition to these, eligibility to the government's food subsidy program and the amount of the food subsidy influence the magnitudes of welfare gains/losses.

The rest of the paper is organized as follows. Section 2 discusses the impacts of the fuel subsidy reform on agricultural commodity markets. This section outlines the empirical strategy, and presents a detailed discussion of the data and results. Section 3 builds on the results in Section 2, and investigates the instantaneous welfare effects of the reform through its direct impact of energy cost and indirect impacts on food prices. Finally, Section 4 presents a concise summary and conclusion.

2. Fuel subsidy reform and market integration

2.1. The law of one price

When trade flow is unrestricted, price difference between two markets must be equal to the shipping cost and transaction cost. Arbitrage should equalize prices across locations to the extent of trading cost. Otherwise, traders could transport commodities, whenever possible, from cheaper markets and sell them at a higher price in other markets, driving prices to parity. This is commonly referred to as the law of one price (LOP). A modified version of the LOP for retail grain trade within a country could be presented as $|P_{jt} - P_{it}| = F_{ijt} + C_{ijt}$, where P_{jt} and P_{it} are price at location j and i at time t, respectively; F_{ijt} is the freight cost to move grains between location i and j at time t; and C_{ijt} includes other transaction costs associated with retail trade in location j by bringing items from market i, and vice versa. Of course, when markets are segmented or whenever there is restriction on trade flow, say due to quota, there would be rent to arbitrage (Barrett, 2001). Fackler and Goodwin (2001) noted that the production of grains in extensive spatial areas and lower value-to-volume ratio for grains present a complex spatial price linkage, and investigation of such an inter-linkage gives an insight into the performance of grain markets.

2.2. Empirical strategy

I use two sets of empirical approach to investigate the effects of removing fuel subsidy on grain price dispersion. First, a short-run assessment of price dispersion changes in the immediate aftermath of the reform is conducted using time-RD design. Second, sDID estimation is conducted using the district's distance from the major market in the capital as a continuous treatment variable, i.e. a factor dictating the magnitude of the fuel subsidy reform's effects on spatial variation in grain prices.

2.2.1. Regression discontinuity (RD) design

I employ a time-RD design to identify any short-run, discontinuous change in price dispersion and price level as a result of the sharp surge in the diesel price in October 2008. In particular, the RD design involves estimating equation 1 below:

$$Y_{it} = \alpha_0 + \alpha_1 Treatment_t + X'\beta + f(time) + \epsilon_{it} \tag{1}$$

...where Y_{it} is price dispersion, i.e. the absolute difference between Addis price (P_{jt}) and the price in district (P_{it}) at time t;[8] $Treatment$ is a dummy equal to one if time is post-reform and zero otherwise; $f(time)$ is a fifth-order Chebyshev polynomial of time;[9] and X is a vector of other covariates such as commodity grade/quality, district fixed effects(FEs), and an interaction term between season FEs and district FEs. Inclusion of $f(time)$ allows for non-linear movement in price dispersion and level over time. I control for the quality of grains traded at every district over time to ensure that the

[8] When I analyze the impact of the reform on price levels, price level in district i at time t is also used as dependent variable.

[9] A robustness check is conducted by varying the degrees of the time polynomial.

price of the same quality grain in district i is compared with its price in Addis.[10] The inclusion of district FEs takes care of time invariant market/district specific factors, such as distance, geographic accessibility, climatic conditions, agroecology, and agriculture production potential. In addition, transportation cost and the resulting grain price dispersion could be different based on weather conditions as well as on agricultural seasons such as between planting and harvesting seasons. For instance, districts with all-weather roads might experience different price dispersion patterns across seasons relative to districts that have dry-weather roads only. In addition, during the harvest season cash-constrained farmers boost grain supply, which drives prices down, especially in rural areas. While, at the end of the dry season farmers usually run out of food stocks and are forced to buy grains, typically from the nearby urban markets (see Moyo and Harou (2013); Arndt et al. (2001); Barrett (1996)). Inclusion of interaction between season FEs and district FEs would account for such intra-annual district-specific factors.

The impacts of the reform on price dispersion would be given by:

$$\alpha_1 = \lim_{t \downarrow Oct\ 2008} \mathbb{E}(Y_{it} \mid t_{it} = t, X_{it}, f(t)) - \lim_{t \uparrow Oct\ 2008} \mathbb{E}(Y_{it} \mid t_{it} = t, X_{it}, f(t))$$

, which can be considered as the average causal effect of the reform on price dispersion (and level) at the time of the reform:

$$\alpha_1 = \mathbb{E}[Y_{it}(Treatment_{it} = 1) - Y_{it}(Treatment_{it} = 0) \mid t_{it} = Oct\ 2008] \qquad (2)$$

...where t refers to time (see Imbens and Lemieux, 2008).[11]

[10] The five grains analyzed in this study have different grades. Wheat, barley, and 'teff' come in three grades: white, mixed, and black. Sorghum has four types (yellow, white, red, and mixed). Maize has one grade only.

[11] As we cannot observe two values of Y, under treatment and non-treatment, we have to rely on averages close to the treatment cut-off, i.e. immediately after ($t \downarrow Oct\ 2008$) and before ($t \uparrow Oct\ 2008$) the reform. To justify this averaging, continuity of conditional regression (or conditional distribution) at point of treatment (in Oct 2008) is required (Imbens and Lemieux, 2008)

To study the spatial heterogeneity in the reform's effect on price levels and dispersion, I estimate the equation 1 with an additional interaction term between *Treatment* and a variable indicating in which driving distance interval (from Addis) district i is located:

$$Y_{it} = \alpha_0 + \alpha_1 Treatment_t + \phi Treatment_t * DistanceIntervals_i + X'\beta + f_i(time) + \epsilon_{it} \quad (3)$$

...where $DistanceIntervals_i$ is the driving distance (from district center to Addis) interval (100–199 km, 200–299 km, ..., 1100–1199 km) in which district i is located. The treatment effects of the reform on districts location in the omitted interval (0-99 km) is given by α_1. The expectation is that districts which are farther from Addis would experience higher increases in price dispersion.

2.2.2. Spatial Difference-in-difference (sDID)

The removal of the fuel subsidy uniformly increased the price of diesel in all parts of the country. This, however, does not mean that all districts have been affected equally by the increase in fuel cost. The reform could affect the markets in the remote districts and those near Addis differently. In fact, transportation cost (as a result of higher fuel price) would be cumulatively higher the farther a district is from major consumer centers. For instance, holding other factors such as agricultural potential, road infrastructure, consumption behavior, etc. constant, districts within 100 km from the capital would face very little increase in transportation costs relative to, say, those that are 400 km away. I leverage this fact to conduct sDID estimation, by using districts' distances from Addis as a continuous treatment variable. The driving distance is imputed using GIS network analysis (see Section 2.4.3 for details).

Specifically, the sDID method involves estimating the equation below:

$$Y_{it} = \pi_0 + \pi_1 Post_t + \pi_2 Distance_i + \pi_3 Post_t * Distance_i + X'\Pi + e_{it} \quad (4)$$

...where Y_{it} is grain price dispersion in district i at time t. $Distance_i$ is the total driving distance from the centroid of district i to Addis on the road network. $Post_t$ is a dummy variable equal to one for time periods after October 2008, and zero otherwise. And X is a vector of other covariates, including commodity grade, month of the year (MOY) FEs, region FEs, and the district's distance from the regional capital or another major regional city.[12]

This framework would be used to estimate the long-run impacts of removing fuel subsidy on price dispersion between Addis and rural areas. Districts that are close to the capital are expected to experience lesser difference in relative price, relative to Addis. Whereas, shipping grains from districts that are located farther away is anticipated to become more expensive, and hence price differentials between these districts and the capital are likely to increase.

2.3. Data

This section of the paper uses a highly disaggregated district/*woreda*-level price data from 1996 to 2013 that was collected by the Ethiopian Central Statistics Agency (CSA) in its Producer Price and Retail Price Surveys.[13] For districts located outside the capital, monthly farm-gate/producer price data for major cereals is aggregated at district level, the second lowest administrative division. For survey purposes, CSA divides each district into enumeration areas (EAs), which are further divided into farmers' associations/FAs. The producer price data is collected from selected FAs or by surveying markets near the selected FAs. Therefore, the panel data is constructed by aggregating the data at district level in such a way that the median price from the surveyed FAs within a district forms the district's price.

[12] I impute distance from up to three major cities in the corresponding region. The distance from the nearest major regional city is used as a control variable.

[13] 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*.

In addition, monthly retail prices of the same quality grain in Addis are used as an indicator of price level in the capital. Both the producer and consumer price surveys include information on the grade of each grain. I use the producer price as prices the farmers in each district garner for their products, and consumer price in Addis is used as the prices consumers in the urban centers pay for the same quality grain.[14]

Global crude oil price data is from the World Bank's Global Economic Monitor (GEM). Quarterly fuel prices data is extracted from annual reports of the National Bank of Ethiopia/NBE(2007–2013); and monthly diesel price data is from the Retail Price Survey of CSA. The GPS coordinates of all types of roads is from the Ethiopian Road Authority. Monthly grain import and export volume and value data is from the Ethiopian Revenues and Customs Authority.

2.4. Results

2.4.1. Descriptive

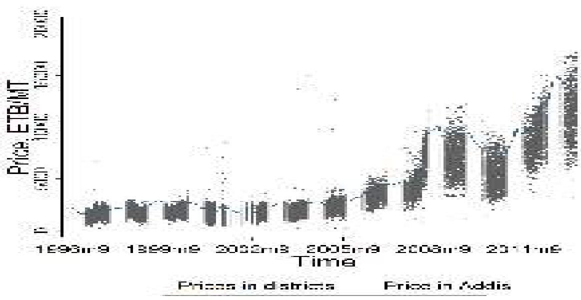
Since late 2005 to the last quarter of 2008, grain prices increased substantially. Sharper price increases were recorded in 2007 and the first three quarters of 2008. In the last quarter of 2008, grain prices started to decrease after an extended period of inflation. This coincides with the stabilization of global commodity prices. The price decline continued until 2011, and then prices started rising again. Figure 2 shows the price dynamics for four of the five grains analyzed in this study ('teff', wheat, maize, sorghum and barley).[15]

[14] The use of producer/farmgate prices in rural areas and consumer/retail prices in Addis could potentially cause upward bias in the welfare loss estimates in rural areas as some households are net-buyers in rural areas, and buy at consumer prices. In rural areas, there are gap between producer and consumer prices. Net-buyers typically pay more than what farmers receive from selling their outputs.

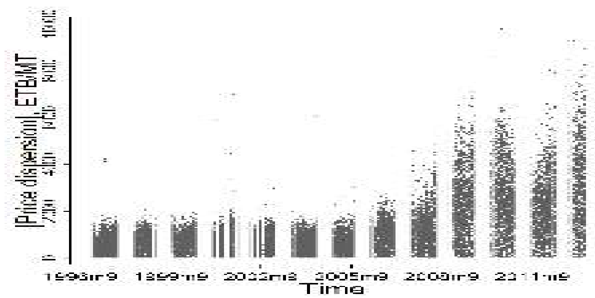
[15] Throughout this paper, I will not show the graphs for barley to save space. For all graphs and maps in the paper, the corresponding graph and map for barley is presented in the Annex.

However, the main focus of this study is not understanding dynamics of price levels. Rather, this study investigates cross-sectional price dispersion and changes in the pattern of grain price dispersion due to higher transportation cost resulting from the removal of fuel subsidy. As Figure 2 shows, cross-sectional price dispersion—as measured by the difference between median price in Addis and prices in other districts—remained low for long time, with minor increases during the 2005–2008 commodity price boom. In the last quarter of 2008, a substantial increase in price dispersion is observed, while the national grain price levels had already started to decline after the peak point of the recent food price crisis. For instance, between 2008 and 2009, the dispersion of 'teff', wheat, maize, sorghum, and barley prices increased by 52, 48, 14, 63, and 34 percent, respectively (see Table A.1 in the Annex). During the final years of the global food price shocks (2007–08), price dispersion had increased mildly. However, a significant surge in cross-sectional price dispersion prevailed since the last quarter of 2008, after the major increase in diesel price following the removal of fuel subsidy.

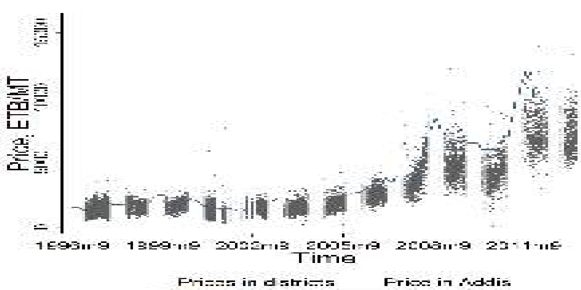
Figure 2: Grain prices and their dispersion over time (1996–2013)



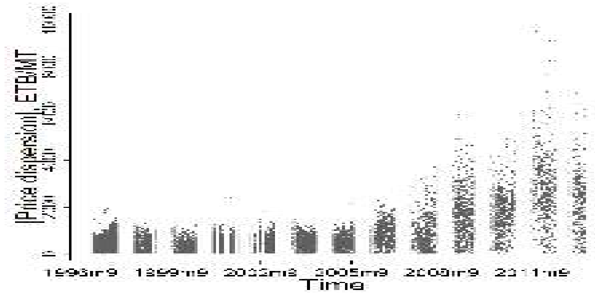
(a) 'Teff' Price



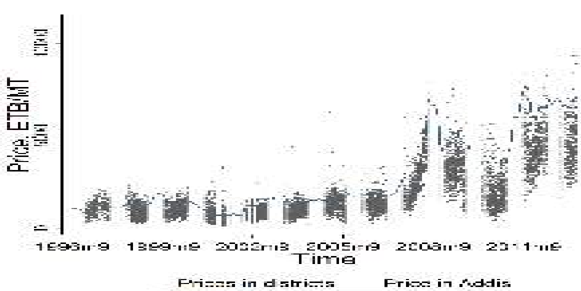
(b) 'Teff' price dispersion



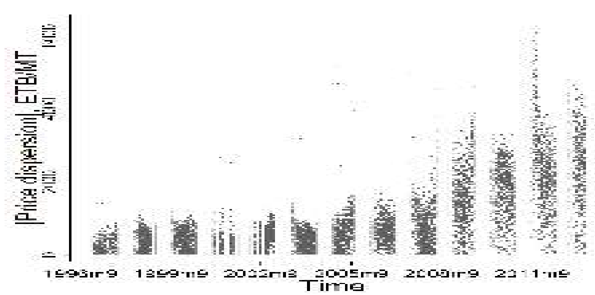
(c) Wheat Price



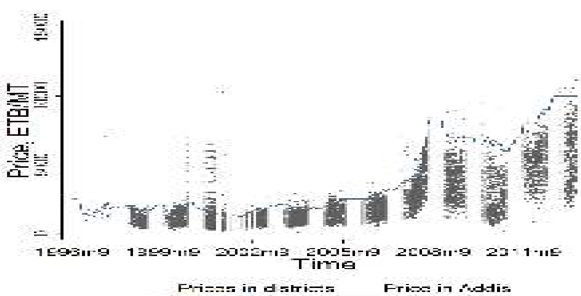
(d) Wheat price dispersion



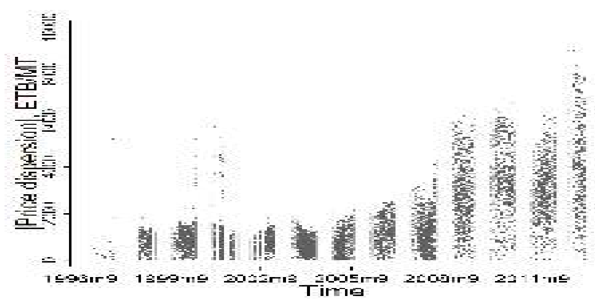
(e) Barley Price



(f) Barley price dispersion



(g) Maize Price



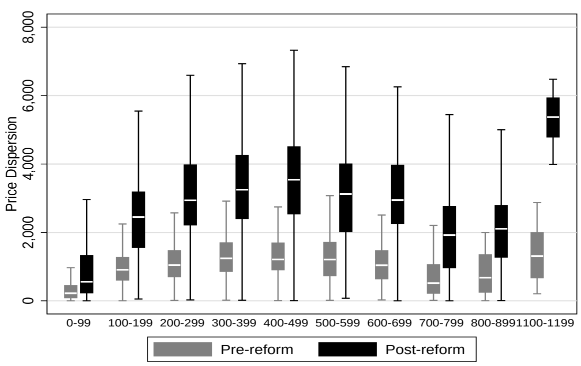
(h) Maize price dispersion

Note: Price dispersion is defined as the absolute difference between median Addis price and the price in each district. The dashed vertical line indicates the time of reform, October 2008.

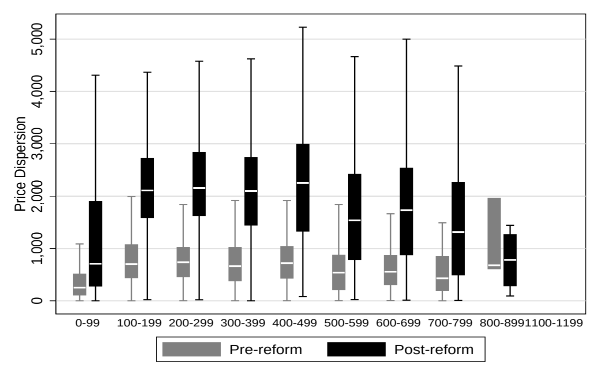
As noted above, it is anticipated that the removal of fuel subsidy would affect grain price patterns in districts that are close to the capital and those farther away differently. Those districts that are near the capital would face lesser increase in transport costs, relative to remote districts. Other factors, such as agricultural potential, distance from other markets, local demand/consumption behavior and so on, remaining constant, the change in price dispersion is anticipated to be lower for nearby districts than those farther from Addis. To investigate this assumption descriptively, I divided the districts into 12 orthogonal groups based on their distances from the capital: from those within 100 kilometers to those 1100-1200 km away, in intervals of 100 km. The price dispersion for these groups of districts, before and after the fuel subsidy reform, is plotted in Figure 3. The difference between median price dispersion after and before the reform increases as the distance of the districts from Addis increase. This shows that, due to the reform, districts farther away from the capital experienced larger increases in dispersion, relative to those closer to this major market.

In addition, there is an interesting price dispersion pattern that holds across the five grains. For districts within 500 km from the capital, we observe widening gap between pre- and post-reform price dispersion as we go farther away from the capital. For districts that are located at more than 500 km from the capital, we observe narrowing gap in (pre- and post-reform) median price dispersion as we go farther from the capital. These districts, which are close to the borders and also tend to have relatively lower agricultural potential, are likely to be trading across the national border, instead of with the capital. As a result, the distance from markets across the borders might be more relevant than the distance from Addis. This explains the smaller gaps between pre- and post-reform price dispersion for the districts, say, 1000 km away from the capital. In addition, in almost all directions, districts closer to the border have lower agricultural potential. They tend to be net-buyers, and they purchase their grains from nearby farming districts. Therefore, another relevant distance might be their distances from these highlands. Finally, districts that are closer to the border might, in general, face higher price both before and after the reform due to the more vibrant economic activities close to the borders. This might explain the higher prices—comparable to those prevailing in the capital—in these very far border districts. I will return to this when I discuss spatial heterogeneity in treatment effects.

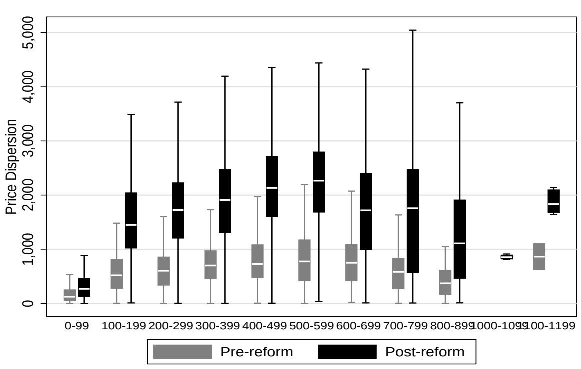
Figure 3: Changes in price dispersion based on the districts' distances from the capital (x-axis), pre- and post-reform



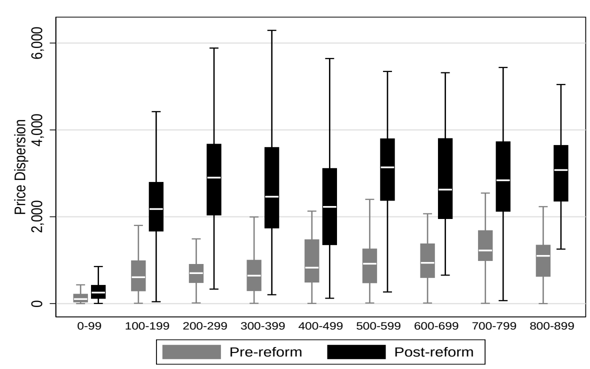
(a) White 'teff'



(b) White wheat



(c) Maize



(d) Yellow Sorghum

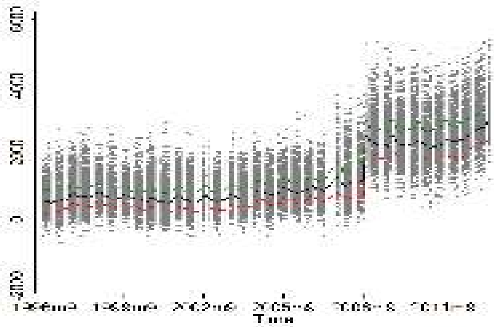
Note: Districts are divided into twelve orthogonal groups based on their distances from Addis, from those within 100 km to those 1100-1200 km away (range of 100km). The bands inside the box of the plots represent the median price dispersion. Price dispersion is in Ethiopian Birr (ETB)/metric ton (MT). For this graph, the pre-reform and post-reform periods are Jan 2005 to Sept 2008 and Oct 2008 to Dec 2012, respectively.

2.4.2. RD result

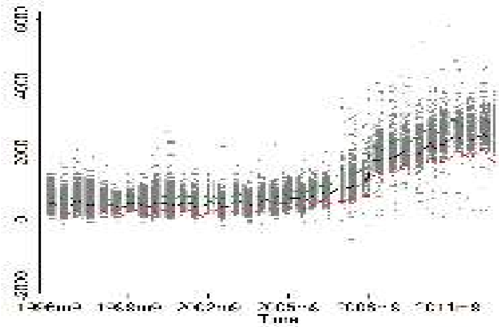
The results from RD analysis on price dispersion, presented in Figure 4 (and Table 1). The results show that increased transportation costs have caused a sharp increase in price dispersion between the capital and other districts. Table 1 presents six estimates for each grain: the first three columns use the full sample (1996–2013) and the last three columns restrict the data to the 2004–2013 period. Column 3, which controls for item grade, district FEs, and interaction between season FEs and district FEs, is the preferred estimate, and all the other specifications tell similar story. The difference between prices in Addis and prices in other districts increased by 1194, 470, 552, 1226, and 752 Ethiopian Birr (ETB)/metric ton (MT) for 'teff', wheat, maize, sorghum and barley, respectively. This amounts to corresponding additional trade margins of 15, 7, 12, 21 and 15 percent (relative to mean price in rural districts for the quarter prior to the reform, i.e. July–September 2008) for the corresponding grains.[16] These increases in price dispersion are national average values. Later, I will bring the distance from the major market in the capital into the analysis to investigate the spatial heterogeneity in treatment effects.

[16]In rural districts, the mean price of 'teff', wheat, maize, sorghum, and barley during July-September 2008 period were 8190, 6580, 4490, 5720 and 5030 ETB/MT, respectively

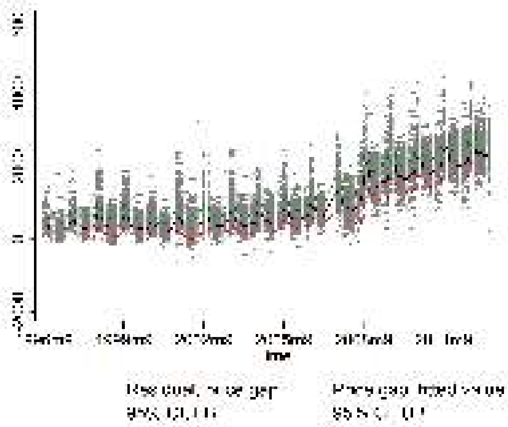
Figure 4: Impact of subsidy reform on price dispersion, RD result



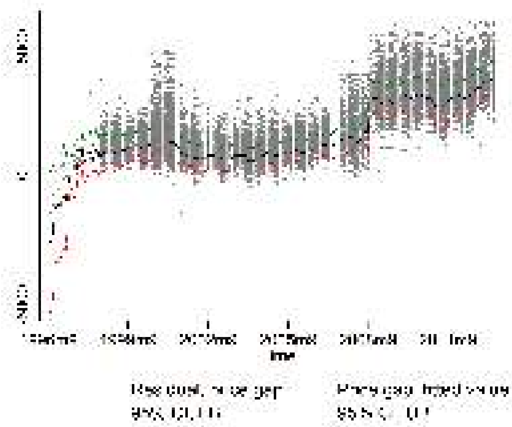
(a) ‘Teff’



(b) Wheat



(c) Maize



(d) Sorghum

Note: Dispersion is measured by absolute deviation of prices in other districts from median price in Addis.

There are a couple of points that need be explained about these results. First, the reform resulted in sharp increase in diesel price, which has decreased subsequently as global crude oil price dropped from $132 to $41 per barrel between July and December of 2008. Despite the decrease in diesel prices, grain price dispersion has persisted and shown a very small decrease during the few months of lower diesel price. The persistence of higher relative price in urban centers might be explained by imperfections in transportation services market (see Rancourt et al. (2014)) and hysteresis in urban grain prices due to imperfect competition in grains market (see Osborne (2005)). Second, the treatment effect is much lower for wheat than other grains. The price dispersion increased by 8% only. This could partly be because of the government's food subsidy scheme that provided wheat and other non-cereal edibles to the urban ultra-poor. The distribution of subsidized imported wheat could have been dampening the price of wheat in the capital, and, in effect, easing the increase in price dispersion resulting from higher transportation cost after the fuel subsidy reform.[17]

The above results are robust to changes in specification, clustering of the standard errors at different levels, controlling for import and export of grains, inclusion of MOY FEs, restricting the analysis to districts that have complete price information around the time of the subsidy reform, and changing the analysis timeframe.[18] Table 1 presents part of the robustness checks.[19] The standard errors presented in Table 1 and Figure 4 are multi-way (district-year) clustered (see Cameron and Miller (2015)). The result is also robust to clustering of the standard errors at district level. I also re-estimated equation 1 with different degrees of the time polynomial, and the estimation results with these different order polynomials are similar to the main results.

[17]The short-lived food subsidy scheme could only have short-run effects on price dispersion. The RD design picks on this short-run effect. But, no long-run effect is expected and the sDID estimate for wheat need not be smaller than that of other grains.

[18]Price dispersion is defined as the absolute price difference between the capital and each district. This makes the dependent variable non-negative. However, only a very small fraction of the total observation is actually zero. Applying censored regression also gives similar results (see Table A.12). However, I had to make a couple of compromises in the empirical implementation of panel tobit model: 1) I use interaction between region FEs and season FEs, instead of the preferred control variable for intra-annually varying district-specific factors (i.e. interaction between district FEs and season); and 2) the standard error were not made robust to clustering.

[19]Some of the robustness check results are suppressed to save space. For readers who are interested in these omitted robustness checks, please review the online appendix.

Table 1: Impacts (ATEs) of fuel subsidy reform on price dispersion, RD result with multi-way clustered standard errors

	Full sample (1996-2013)			Restricted sample (2004-2013)		
	(1)	(2)	(3)	(4)	(5)	(6)
'Teff'	1180***	1187***	1194***	897***	862***	878***
	(199.6)	(223.6)	(211.1)	(132.3)	(121.8)	(126.8)
N	74703	74703	74703	40772	40772	40772
Wheat	467**	469**	470**	942***	920***	915***
	(178.0)	(153.0)	(164.6)	(107.5)	(119.2)	(99.7)
N	34838	34838	34838	16500	16500	16500
Maize	531*	536***	552***	656**	562***	611***
	(214.1)	(124.6)	(128.6)	(203.4)	(143.8)	(130.1)
N	28571	28571	28571	18970	18970	18970
Sorghum	1235***	1236***	1226***	1237***	1177***	1182***
	(151.5)	(142.1)	(141.0)	(134.1)	(115.3)	(125.2)
N	28243	28243	28243	18379	18379	18379
Barley	730***	728***	752***	1153***	1061***	1095***
	(208.5)	(146.5)	(156.0)	(128.8)	(168.0)	(137.9)
N	40539	40539	40539	17843	17843	17843
Covariates:						
Item grade	Yes	Yes	Yes	Yes	Yes	Yes
District FEs	No	Yes	Yes	No	Yes	Yes
MOY FEs	No	Yes	No	No	Yes	No
District FEs*Season FEs	No	No	Yes	No	No	Yes

Note: All regressions include fifth-order polynomial of time. Multi-way (district-year) clustered standard errors are in parentheses: * $p<0.05$, ** $p<0.01$, *** $p<0.001$

The inclusion of import and/or export volumes for each grain does not change the result either. This might be particularly pertinent in this context because the government has been distributing imported wheat under its urban food subsidy scheme, and has imposed (and later lifted) export bans on grains in an effort to stabilize domestic food price.[20] The food subsidy scheme, which offered subsidized wheat, edible oil, sugar, and other goods to systematically selected poor households in some urban centers, was also implemented using imported wheat. This study uses farm gate prices in rural areas (and retail prices in the capital). The markets in rural districts would not be directly affected by the food subsidy. However, the capital might experience lower wheat prices due to distribution of imported wheat at subsidized prices.[21]

The panel data is unbalanced since some districts do not have price data for parts of the timeframe under study. To check the robustness of the result to irregular reporting, I restrict the analysis to districts that have data for at least 75% of the time around the reform period (2008–2009).[22] The result (presented in Table A.2) is consistent with the main estimation. For all grains, ATEs are higher when the analysis is restricted to districts with 'complete' information.

Spatial Heterogeneity: It is very likely that the reform could affect markets in various parts of the country differently as they are located at different distances from the major national markets; and access to roads is far from being uniformly distributed across districts. To document any spatial heterogeneity in the treatment effects of the reform on price dispersion, I conduct a spatial heterogeneity analysis. I divide the districts in the sample into twelve sub-groups based on their driving distances from Addis, in a range of 100 km (i.e. 0-99.9 km, 100-199.9 km, and so on). The interaction between these distance intervals and the treatment variable is used to pin-down spatial

[20] According to Admassie (2013), the export of major cereals ('teff', wheat, maize and sorghum) was totally banned in December 2006. In June 2008, the ban was extended to all cereals. Maize and Sorghum export ban was lifted in July 2010 (IRIN, 2010). In 2011, maize export ban was re-imposed (Seyoum, 2011).

[21] Price of other grains could also be affected indirectly by the food subsidy scheme due to potential substitution between wheat and these grains.

[22] For 'teff' and sorghum, which happen to have more complete data, I restricted the analysis to districts that have price data for 100% of the months in the 2008–2009 period. That includes districts with price report for at least one grade of 'teff' and sorghum every month in 2008 and 2009. For barley and wheat, district with data for at least 80% of the months for at least one grade are used. For maize, which has only one grade, districts that have price data at least 75% of the time (in 2008–2009) were included in the analysis.

heterogeneity in the treatment effects, if it exists.

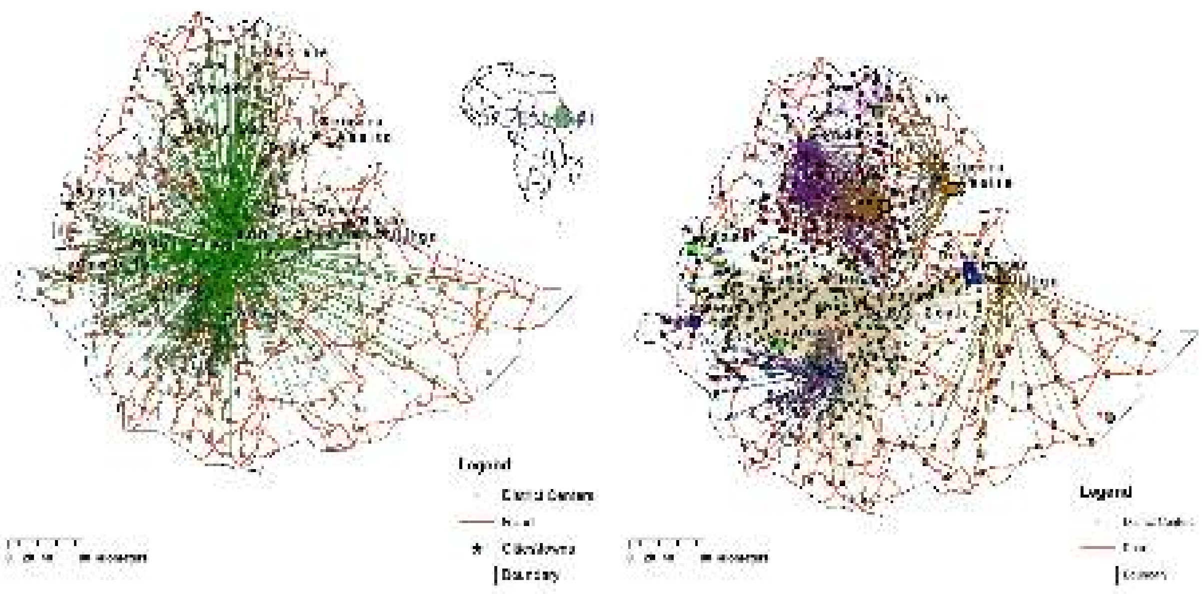
The distance of each district from Addis and the corresponding regional capital is imputed using GIS network analysis. This method traces the shortest distance from the centroid of a district to Addis (or the regional capital) on the road network. The imputation involves three steps. First, I identify the geographic centroid of the district, which might not necessarily be the administrative center nor the location of a market in the district. Therefore, I allow a maximum tolerance of 50 km from this centroid to the nearest road. Second, I generate road network data using GPS coordinates of all types of roads (asphalt, gravel, and dry-weather roads). Finally, I implement network analysis to estimate the total driving distance between the district centroid, and the national and regional capitals. Figure 5 (a) shows the imputation of each district's distance from Addis. This distance is used as a continuous treatment variable in the sDID approach.

In addition to distance from the national capital, which is the main consumer center, distances from regional capitals and major regional towns also matter, and we might want to control for this distance.[23] Accordingly, I impute distances from up to three major cities in each region. The distance from the nearest major regional city is used as a control variable.[24] Regional capitals and other major cities are the next significant buyers of grains, after Addis. They also serve as a link between Addis and rural areas as they are collection centers for large traders. Figure 5 (b) shows the imputation of distances from the major regional cities.

[23] As a robustness check, I use population weighted distances from Addis and the nearest regional city, using these two cities' populations as weights. The result (see Table A.14 in the online Annex) is consistent with main findings shown in Table A.14.

[24] In Oromia and Amhara regions—the two largest regions in terms of population and the 2^{nd} and 3^{rd} largest regions in terms of land area—I imputed distance from three major cities in each region: Jima, Nazret and Debre Zeyit in Oromia, and Bahir Dar, Gonder and Dessie in Amhara region. In Afar region, distance of each district from the former and current capital (i.e. Asaita and Semera) is imputed. In these three regions (Oromia, Amhara, and Afar), distance of a district from the nearest regional city is used as a covariate. In the other regions, distance from the regional capital is used as a covariate.

Figure 5: Imputation of distance from each district's center to Addis, and regional cities



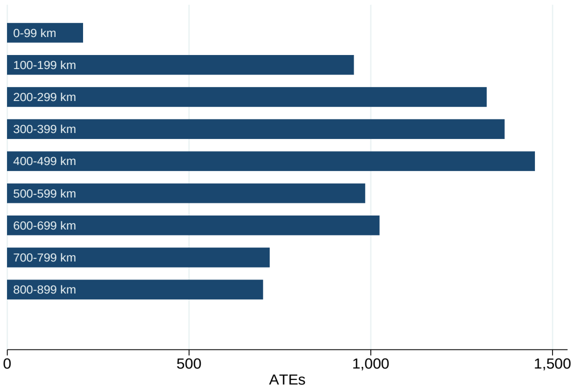
(a) Distance from Addis

(b) Distance from regional cities

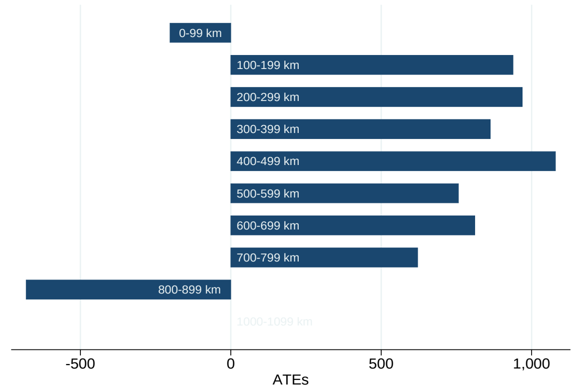
Note: The network analysis produces a straight line joining an origin to a destination. However, it uses the road network to impute the driving distance. The actual route is not shown. The gray circles are proximate locations from which the driving distances are imputed, for every green training that represents the district's centroid.

Table A.3 (in the annex) presents the estimated treatment effects for districts at different distances from Addis. To facilitate visual interpretation of these estimates, I plot the ATEs on bar graphs (Figure 6). For almost all of the five grains, except barley, the farther the districts are from Addis the higher the treatment effect. This is a clear evidence that the increases in price dispersion are actually driven by higher transportation cost after the removal of fuel subsidy. For instance, when the distance interval increases from (0, 100) to [400, 500) km, the price dispersion for 'teff' and wheat progressively increase from 251 and -346 ETB/MT to 1599 and 1352 ETB/MT, respectively. For all grains, except barley, this pattern holds true for up to 500 km. For districts that are more than 500 km from Addis, the price dispersion decreases. More on why this pattern might have emerged is discussed below.

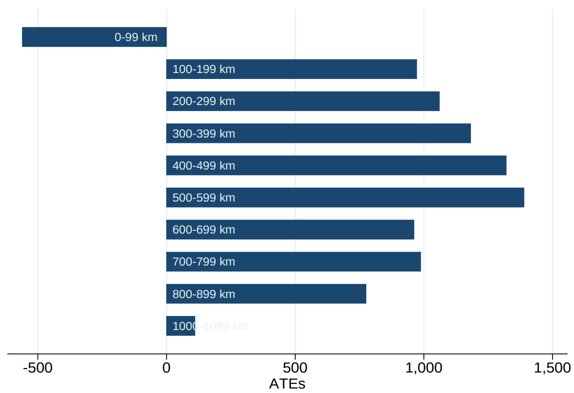
Figure 6: Spatial heterogeneity in price dispersion effects, ATEs over a range of 100 km driving distance radius from Addis



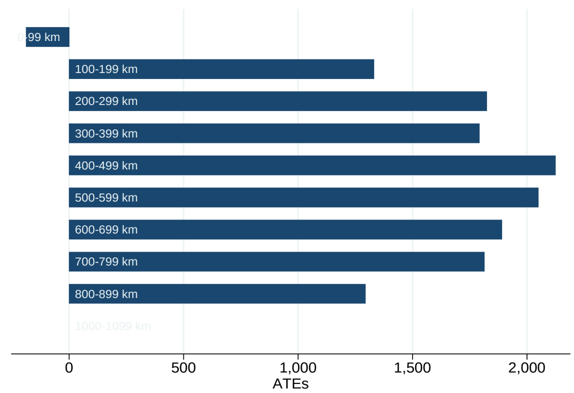
(a) ‘Teff’



(b) Wheat



(c) Maize



(d) Sorghum

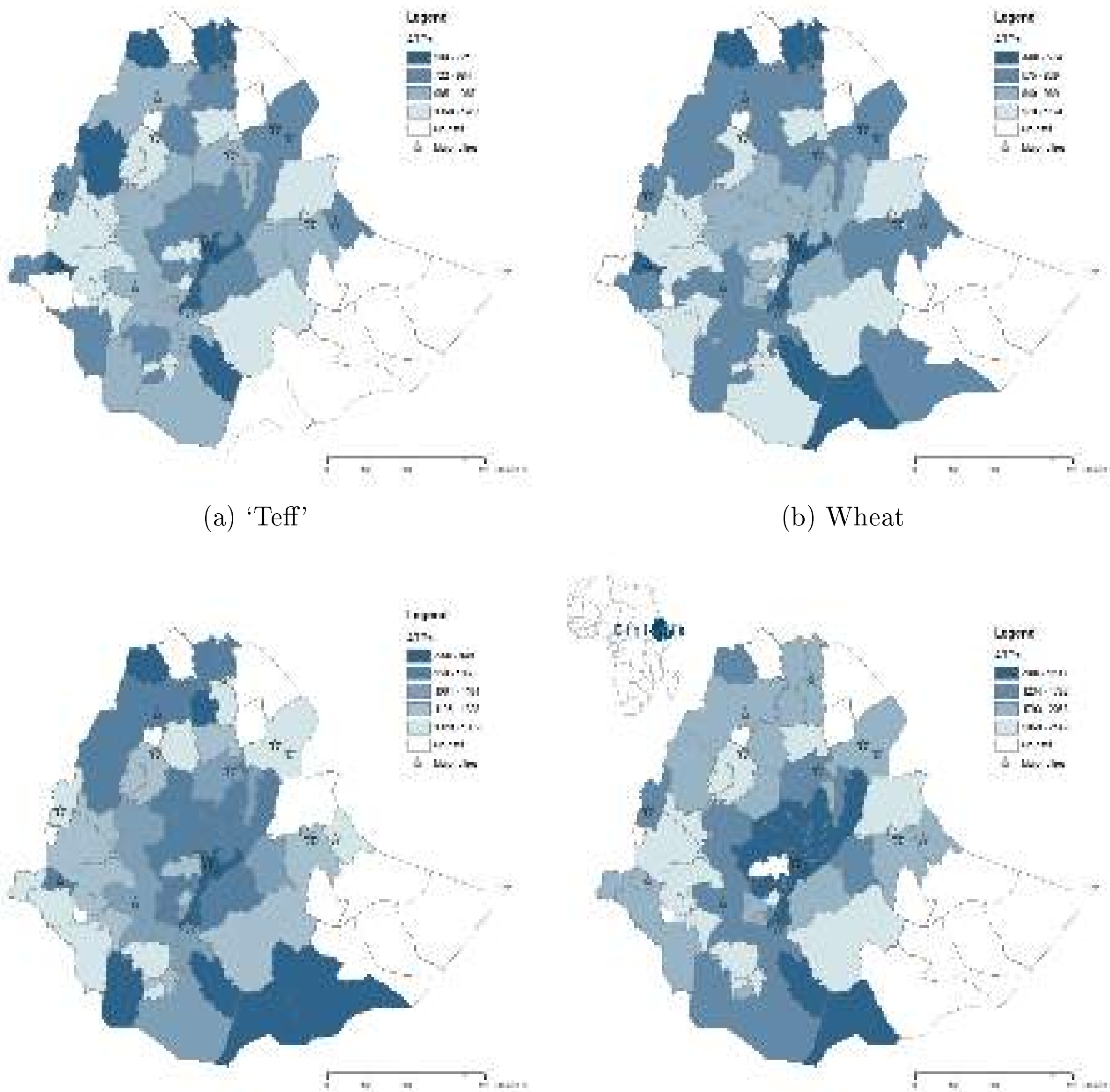
Note: ATE on price dispersion are estimated interaction of treatment with distance intervals, using RD design.

I mapped these ATEs (presented in Table A.3 and Figure 6) to better understand the spatial difference in the reform's effects on price dispersion. Figure 7 maps the ATEs at zone level, and it provides a perspective as to which parts of the country have experienced higher/lower price decreases/increases relative to the capital.[25] Clearly, there are pronounced heterogeneities in treatment effects across spaces. Districts near the capital experienced less price dispersion. As we go farther from Addis, the price

[25] Note that districts within similar distance from Addis have different ATEs because differences in other district-specific factors accounted for by including district FEs.

dispersion increases, albeit heterogeneously. Looking at the issue from production side only, it is likely that districts that experienced higher decreases in relative price are remote areas with higher agricultural potential, while those that experienced relative price increase are remote areas with low agricultural potential and hence tend to be net-buyers. For all of the five grains, a common observation is that the less productive zones in Afar, Somali, and Tigray regions as well as parts of Gambela region, all of which also happen to be closer to the national borders, experienced relatively smaller decreases in price or smaller increases in price dispersion. These districts are likely to trade across national borders, instead of with the capital. In effect, the distance from markets across the borders might be more relevant than the distance from Addis. On the other hand, the areas that experienced lesser price dispersion vary across commodities. In addition to distance from Addis, this could partly be a result of differences in production potential of the zones; and whether (or not) the commodity is a staple crop in these zones.

Figure 7: Spatial heterogeneity in treatment effect of the reform on price dispersion: ATEs by zone



(a) ‘Teff’

(b) Wheat

(c) Maize

(d) Sorghum

The results above confirm that the reform has led to increases in cross-sectional price dispersion, with some areas experiencing lower prices and others facing higher grain prices. Thus, the net effect of the reform on national grain price levels is not clear.

To document this, I estimate Equation 1 using price level as a dependent variable on dataset from all districts in the sample. The results (see Figure A.2 and Table A.4 in the Annex) show that the reform did not cause any increase in overall price level. None of the estimated ATEs is statistically significant. This result is robust to changes in specification and clustering of standard errors at different level. Table A.4 presents the estimates under different specifications, by including/excluding import/export volume and inclusion of district FEs and MOY FEs instead of interaction between season FEs and district FEs. Restricting the analysis to the 2004–2013 period also gives qualitatively similar results as using the full sample (1996–2013). Replacing distance from Addis with population weighted distance from the national and regional capitals also does not substantially affect the results.

As noted in the introduction, the input cost channel from higher fuel cost to grain prices is limited as agriculture is less mechanized and energy intensity in farming is very low. Even though higher fuel cost has increased cross-sectional price dispersion, the increased dispersion partially reflects decreases in grain prices in rural agricultural areas and/or increases in grain prices in urban centers and low agricultural potential rural areas. To investigate the difference in price levels across districts at different distances from the capital, I estimate equation 3 with price level as the dependent variable. The result, presented in Table A.5, shows that districts which are located increasingly farther from Addis experienced even more decreases in prices after the increase in diesel price following the removal of fuel subsidy.

2.4.3. SDID Result

The sDID estimation is implemented using distance from the capital as a continuous treatment variable. Table 2 presents the results. The impact of the reform on spatial price dispersion is captured by π_3, the coefficient of $Post * Distance$ in equation 4. I have controlled for other relevant covariates such as commodity grade, interaction between season FEs and region FEs, and distance from the nearest major regional town. Standard errors are multi-way (district-year) clustered. The impact estimates capture the changes in per ton price-dispersion due to the reform for every 100 km a district is farther from Addis.[26] Assuming that the resulting dispersion increase is driven by decrease in prices in rural districts, a farm household residing in a district 100 km away from the capital receives (on average) 103, 90, 98, 204, and 159 ETB less for every 1 MT of 'teff', wheat, maize, sorghum, and barley it sells, respectively.[27] To make interpretation of these results more tractable, it is useful to know average yield of a typical farm household in Ethiopia for the growing season prior to the reform. The average yields of 'teff', wheat, maize, sorghum, and barley in 2007/8 were 1.2, 1.6, 1.9, 1.7 and 1.1 MT per hectare, respectively (Rashid, 2010). The average distance of districts (in the sample) from the capital is about 350 km. Therefore, an average farm household that owns a hectare of land, and is located at 350 km from the capital would earn 433, 504, 652, 1214 or 612 ETB less from the selling 'teff', wheat, maize, sorghum, and barley production on its one hectare land, respectively.[28]

The above example is a story from net-seller households' perspective. One can also present a narrative from the perspective of net-buyer households in rural districts or consumers in the capital. Net-buyer households located at various distances from the capital have experienced corresponding lower prices, relative to prices prevailing in the capital. Households in Addis face corresponding price increases on every unit of the grains they purchase, which are transported from grain producing areas that are located at various distances. These five grains account for a significant share of households' total food expenditure. For instance, in 2004, an average urban resident consumes 61, 20, 10, 9 and 4 kg/year of 'teff', wheat, maize, sorghum, and barley, respectively (see Berhane

[26]Distance is measured in 100s of kilometers when it is interacted with *Post*.

[27]Obviously, the increase in dispersion is the result of price increases in Addis and/or price decreases in the districts. I disentangle these two components of change in price dispersion.

[28]This calculation is assuming that the household would sell all of its produce. This is a very strong assumption. In the welfare analysis, I use households' actual net-sell of grain from a survey dataset.

et al. (2011)). Therefore, the corresponding higher prices urban residents pay for these grains could reduce their real incomes. On the other hand, due to price-dampening effects the reform would have on remote rural markets, net-buyers in rural areas would pay (relatively) lower prices. I will return to this discussion in the following section using actual price changes across space, and consumption and production patterns of households from a nationally representative household survey.

Table 2: Impact of the reform on price dispersion: sDID result

	(1) Teff	(2) Wheat	(3) Maize	(4) Sorghum	(5) Barley
Distance*Post	102.9**	89.9*	98.2***	204.2***	159.2**
	(38.4)	(43.3)	(29.4)	(35.4)	(55.2)
Distance, 100 km	38.3*	-24.9	23.8	-1.7	-36.1
	(19.3)	(15.7)	(14.7)	(29.8)	(23.4)
Post	1147.9***	1166.0***	966.4***	941.3***	1229.0***
	(158.9)	(152.4)	(118.9)	(161.0)	(180.8)
N	66817	31182	26155	26364	36497

Note: Multi-way cluster (year and district) robust standard errors (see Cameron et al. (2008)) in parentheses: *** p<0.01, ** p<0.05, * p<0.1. Covariates included as control variables are commodity grade, interaction between season FEs and region FEs, and the district's distance from the regional capital or another major regional town.

The result is robust to clustering of standard errors at district level, and changes in specification. District cluster standard errors estimates are presented in Table A.6 (see Annex).[29] In addition, I also check the robustness of the result when the relevant distance is changed. In the main result, distance of each district from the capital was used as a continuous treatment variable, while distance from the nearest regional city was included as a covariate. The main argument for doing so was that Addis is the country's major consumer center and its population is by far larger than that of the next 9 regional cities combined. One might, however, argue that distance from the regional city could also matter. To investigate this, I constructed a weighted distance by weighting the distance of districts from Addis and the corresponding regional cities

[29] Note that applying censored regression gives similar result (see Table A.16 in the online Annex).

by the population size of the capital and the regional cities.[30] The results are very similar to those presented above (see Table A.15 in the online Annex).

3. Welfare Implications

3.1. Theoretical Framework

Deaton (1989) and Deaton (1997) postulated that changes in grain prices result in first-order/instantaneous welfare changes, proportional to the share of expenditure on grains in total household expenditure, and income from grain sales in household income. The framework assumes that households do not have sufficient time to change their production and consumption behavior. This is particularly true in the case of the five grains analyzed in this study. First of all, these grains are major staples and an immediate adjustment in consumption behavior is unlikely to occur. In addition, the reform was implemented in October, after almost all of the production decisions for the year have already been made. In the long-run, however, sufficient time for adjustment could attenuate the welfare effects as households revise their production and consumption decisions. In this section, I focus on the instantaneous welfare effects of the grain price changes resulting from the fuel subsidy reform.

In order to reduce the welfare effects of the fuel subsidy reform, the government launched a food subsidy scheme targeting the urban poor. To investigate the instantaneous welfare effects of changes in grain prices associated with the removal of fuel subsidies, and the simultaneous government effort to curb its adverse welfare effects through provision of food subsidy to the urban poor, I modify Deaton's framework. More specifically, I explore the welfare implications of changes in prices resulting from the removal of the fuel subsidy, and explicitly account for the potential counter effects of the simultaneous food subsidy scheme.

[30] Recall that this population-weighted distance is also used for checking robustness of the spatial heterogeneity analysis of the RD design.

Suppose that a modified version of the indirect utility function of a typical household, i, that earn wage income from employment, $w_i L_i$, and/or profit from own enterprise, π_i, is given by:[31]

$$V_i(P_i^d, w_i, \pi_i, t_i) = Max\big[U_i(q_i^d, L_i) \;\; s.t. \;\; \big(P_i^d - t_i \mathbb{I}\big[Y_i < \bar{Y}\big] P_i^d\big) q_i^d = Y_i\big]$$

$$= \psi_i(Y_i, P_i^d - t_i \mathbb{I}\big[Y_i < \bar{Y}\big] P_i^d) \tag{5}$$

...where $V_i(.)$ is indirect utility function; P_i^d is a price vector paid for an output vector, q_i^d, consumed by household i—I broadly classify consumption into two: the five grains and energy (from here forward, item j), and other food and non-food items; $U_i(.)$ is direct utility function, which depends on consumption and labor, L_i; w_i is wage rate household i faces; $Y_i = w_i L_i + b_i + \pi_i$ is household i's income from all sources; b_i is unearned income (rental income, property return etc); and t_i is a vector of government subsidy/transfer on each unit of q_i^d purchased by household i as a proportion of its unit price. Obviously, government subsidy is equal to zero for most goods and for most households. Let us assume that households with income below a threshold/poverty line, call it $\bar{Y}$, would get a subsidy for selected food items. The indicator function $\mathbb{I}[Y_i < \bar{Y}]$, which is equal to one when a household's income from all sources is below $\bar{Y}$, reflects this. This assumption captures the government's policy during the period: the government offered subsidized wheat, edible oil, sugar and other food items at a price below the market rate; poor households were selected by local administrators; and longer waiting time to access these subsidized items also screens out the non-poor households.

The effect of changes in price of the five grains and energy, j, on household $i's$ real income can be assessed by looking at the change in indirect utility following a change

[31] For standard indirect utility function, see page 57 of Mas-Colell et al. (1995).

in price, ∂P_{ij}.

$$\frac{\partial Vi(.)}{\partial P_{ij}} = \frac{\partial \psi_i}{\partial Y_i}\frac{\partial \pi_i}{\partial P_{ij}} + \frac{\partial \psi_i}{\partial p_{ij}}(1 - \mathbb{I}[Y_i < \bar{Y}]t_{ij}) \tag{6}$$

One can rewrite parts of equation (6) to facilitate interpretation. Using Roy's identity, $\frac{\partial \psi_i}{\partial P_{ij}} = -\frac{\partial \psi_i}{\partial Y_i} q^d_{ij}$, and Hotelling's lemma, $\partial \pi_i / \partial P_{ij} = q^s_{ij}$, (Mas-Colell et al. (1995): pp 73 and pp 138), I rewrite the welfare effects of changes in price of commodity j as:

$$\frac{\partial Vi(.)}{\partial P_{ij}} = \frac{\partial \psi_i}{\partial Y_i}[q^s_{ij} - (1 - \mathbb{I}[Y_i < \bar{Y}]t_{ij})q^d_{ij}] \tag{7}$$

To estimate amount of transfer (CV_i) required to keep household i at its initial level of utility after the price changes, it is informative to express equation 7 in terms of compensating variation (Deaton, 1989). The amount of such (positive/negative) transfer required, as a share of income, would be: [32]

$$CV_i = [(1 - \mathbb{I}[Y < \bar{Y}]t_{ij})\frac{q^d_{ij} P_{ij}}{Y_i} - \frac{q^s_{ij} P_{ij}}{Y_i}]\frac{\Delta P_{ij}}{P_{ij}} \tag{8}$$

This result characterizes the households that might have experienced welfare losses/gains due to the removal of fuel subsidy and the simultaneous introduction of a food subsidy scheme. A household could be a producer as well as a consumer of grains, and hence, the welfare impacts of changes in grain prices depends, in part, on share of grains in the household's total consumption expenditure ($\frac{q^d_{ij} P_{ij}}{Y_i}$), what Deaton (1989) calls "consumption ratio", and share of grain sales revenue in total household income ($\frac{q^s_{ij} P_{ij}}{Y_i}$), "production ratio". In addition, households' eligibility to and the amount of government subsidy affects the welfare effects of the reform. As extensively documented in Section 2, the removal of fuel subsidy increased grain prices dispersion between Addis and rural districts—dampening grain prices in remote rural areas and/or making Addis relatively more expensive. The change in prices in different parts of the country has been extensively documented in the previous section. All of the other parameters in Equation 8 are imputed from household surveys data in the next subsection.

[32] Note that $\frac{\partial \psi_i}{\partial Y_i}$ is a positive constant. Assume it is equal to unity.

3.2. Empirical test

3.2.1. Data

I use Household Income, Consumption and Expenditure Survey (HICES), which was collected in 2004/05 by CSA.[33] This survey covers 21,595 households that are nationally representative. The unique advantage of HICES is that the recall time for consumption expenditure is a window of few days: enumerators interviewed households twice a week for a month to document food consumption expenditure patterns. For non-food recurring expenditures, weekly recall data was collected over the four weeks period. This addresses the limitation of typical household surveys that depend on recall over extended period.

3.2.2. Result

In this subsection, I estimate the amount of transfers required to enable households maintain their initial levels of utility. To do so, I imputed production and consumption ratios, and the magnitude of food subsidy. The value of grains and energy consumed, and the value of grains produced are imputed using HICES data.[34] The relative magnitude of the government's food subsidy is calculated using the prevailing market price and the price at which the government was rationing subsidized wheat in urban centers, weighted by the share of wheat in household expenditure on the five grains and energy.[35] Finally, these parameters are put together to estimate the amount of transfer

[33] Unfortunately, the latest HICES prior to the 2008 reform was collected in 2004/05. There is no nationally representative household survey data collected in the year immediately before the reform. The parameters of interest could have changed between 2004 and 2008.

[34] The value of grains and energy consumed, $q_{ij}^{d}P_{ij}$, is estimated by $\sum_{k=1}^{6} q_{ik}^{d}P_{ik}$, where k represents the five grains, 1-5, and energy, 6. While, the value of grains produced, $q_{ij}^{s}P_{ij}$, is given by $\sum_{k=1}^{5} q_{ik}^{s}P_{ik}$.

[35] Specifically, the relative magnitude of the government's food subsidy (that provided subsidized wheat) in household $i's$ grain expenditure is given by $t_i = (\frac{P_{i2}^{subsidized}}{P_{i2}^{market}}) * (\frac{q_{i2}^{d}P_{i2}^{market}}{\sum_{k=1}^{5} q_{ik}^{d}P_{ik}^{market}})$, where k=2 refers to wheat. Note that the government's food subsidy scheme also provided edible oil, sugar and other items. These items are not included in the welfare analysis.

required to enable households maintain their initial levels of consumption.

Household expenditure on the grains is estimated by adding the amount of expense on grains and energy purchases to the value of grains consumed out of own production. This expenditure on grains and energy, as a proportion of total household expenditure, provides the "consumption ratio". Even though production information was not collected in HICES, for every expenditure, the sources of income used to purchase the corresponding item were extensively documented. The value of grains produced is approximated by the value of grains consumed out of own production and the amount of agricultural income spent on all other food and non-food items.[36] The value of grain produced, as a share of total household income, gives the "production ratio". Table 3 presents production and consumption ratios for rural and urban households, by per capita consumption quartile. As expected, rural households have higher production ratio than urban households. On average, rural and urban households earn 80% and 6% of their incomes from the five grains, respectively. The poor rural households earn even higher share of their incomes from these grains, and production ratio decreases for higher consumption quartile. Grains and energy also take higher consumption share among rural households (35%) than urban households (23%). Households in the lower consumption quartiles have higher consumption ratios, i.e. they spend higher share of their incomes on grains and energy. Similar comparison between farm and non-farm households is also presented in Table A.8 (see the Annex).

[36] The latter includes incomes from any agricultural products, from grains as well as other outputs. Unfortunately, the expenditure paid using agricultural income is not further divided by sub-components of the agricultural sector. As a result, agricultural income is used as a proxy for income from the five grains.

Table 3: Consumption and production ratios for rural and urban households, by per capita consumption quartile

Household Type	Ratios	Consumption Quartile 1	2	3	4	National
Rural	Production ratio	0.81	0.84	0.81	0.73	0.80
		(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
	Consumption ratio	0.38	0.38	0.35	0.28	0.35
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Urban	Production ratio	0.07	0.08	0.07	0.04	0.06
		(0.01)	(0.01)	(0.01)	(0.00)	(0.00)
	Consumption ratio	0.29	0.28	0.25	0.18	0.23
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Note: Quartile 1 is the lowest quartile.

Regarding prices, I generate a 'consumer price index' for the five grains ('teff', wheat, barley, maize, and sorghum) and energy (diesel, kerosene, and gasoline) by weighting the price of each commodity by its share in the household's total expenditure on these grains and energy.[37,38] The changes in price are weighted by consumption share to form changes in this price index. The changes in the price of each grain in the corresponding zones is captured by spatial heterogeneity of the reforms effect on grain price levels. That is, the ATEs of the reform on grain prices in districts at different distances from Addis (presented in Table A.5, see the Annex) are used as a measure of changes in prices of the five grains in each zone. The weighted mean of ATEs for these grains in each zone is adapted as a measure of average changes in grain prices. The increase in

[37] This means, every household will have a unique 'consumer price index'/CPI_i, which is a function of the household's expenditure share in these grains and energy, and the prices in the corresponding zone. That is, $CPI_i = \sum_{k=1}^{6} P_{ik} * \alpha_{ik}$, where $\alpha_{ik} = \frac{P_{ik}q_{ik}^d}{\sum_{k=1}^{6} P_{ik}q_{ik}^d}$ is the share of item k in household $i's$ total expenditure on grain and energy; and P_{ik} and q_{ik}^d are price of item k in the zone in which household i resides and quantity of item k that household i demanded, respectively. The change in CPI_i is given by $\Delta CPI_i = \sum_{k=1}^{6} \Delta P_{ik} * \alpha_{ik}$.

[38] Households do not necessarily consume diesel and gasoline directly. Instead, cost of services such as transport fare and car fuel are used as proxies for consumption expenditure on these two energy sources. Thus, energy expenditure is equal to households' spending on transport fare, car fuel, and kerosene.

prices of diesel, kerosene and gasoline at the reform time is used as a proxy for the increase in energy cost.

The amount of transfer required to ensure that households maintain their initial levels of consumption is imputed using the parameters discussed above, and the result is presented in Table 4. The table shows that the average amounts of income households lost and the percentage of households that have experienced income losses, by per capital consumption quartile.[39,40] A rural household, on average, lost about 380 ETB due to relative decreases in grain prices in rural areas.[41] The income loss is larger among middle income (those in the 3^{rd} and 4^{th} consumption quartiles) rural households. Urban households, on average, seem to have gained due to the reform. This is especially true among households in the lower quartiles—particularly those eligible for food subsidy. The amounts of gain and loss are average figures, and in all income groups, there are rural and urban households who have benefited from the reform. Table 4 shows the percentage of households who have lost income. In rural areas, about 76% of households have experienced income losses. While, in urban areas only 27% of households experienced real income losses.

[39] The corresponding table for farm and non-farm households is presented in Table A.9, see the Annex.

[40] The amount of income lost is equal to the amount of transfer required to maintain the pre-reform utility levels of households.

[41] This is the amount that need be transferred to these households in order for them to maintain their initial levels of utility.

Table 4: Changes in real incomes of rural and urban households due to the reform, by per capita consumption quartile

Household Type	Variables	Consumption Quartile				
		1	2	3	4	National
Rural	Income loss (ETB)	-249	-386	-433	-460	-380
		(7.2)	(10.1)	(11.1)	(14.6)	(5.5)
	% HHs who lost income	73	78	79	73	76
		(0.9)	(0.8)	(0.8)	(0.9)	(0.4)
Urban	Income loss (ETB)	28	15	16	-2	11
		(4.2)	(8.2)	(7.7)	(5.9)	(3.3)
	% HHs who lost income	26	26	26	29	27
		(0.8)	(1.0)	(1.0)	(0.6)	(0.4)

Note: This table presents the percentage of households that experienced income losses. The remaining percentage of households experienced either no change or positive change in real income.

4. Conclusion

This study uses a policy experiment in Ethiopia and a detailed grain price data to investigate the impacts of fuel subsidy reforms on grain markets, through their effects on freight costs, in developing countries that rely on road transportation to ship grains from production areas to consumer centers. Time-RD and sDID are used to investigate the effects of removing fuel subsidy. In the time-RD design, comparison of average cross-sectional price dispersion immediately before and after the reform identifies discontinuous changes in price dispersion at the time of the reform. The sDID approach, with the distance from the major market center used as a continuous treatment variable, shows how districts at different distances from Addis are affected differently by the increases in fuel cost.

The empirical results show that the removal of fuel subsidy and subsequent surge in diesel price has caused increases in cross-sectional price dispersion. Particularly, remote rural areas have experienced decrease in grain prices, relative to Addis. In addition, there is pronounced spatial heterogeneity in the treatment effect: the farther a district is from the capital the larger the declines in the relative grain prices.

The changes in price dispersion, which is analogous to changes in relative price levels in the corresponding locations, would have implications on real incomes of households. I investigate this instantaneous welfare effects of these changes in relative grain prices for each district following the removal fuel subsidy and the government's simultaneous effort to contain the welfare implications of higher food prices in urban centers through a food subsidy scheme.

I estimate the parameters that are relevant for empirical analysis of welfare effects on different groups of households using a nationally representative household survey. In both urban and rural areas, some households benefited and others suffered income losses. As expected, farm and rural households earn higher share of their incomes from grains, and spending on these grains also constitutes higher share of consumption expenditure among these households. On the other hand, non-farm and urban households earn small share of their incomes from grains and expenditure on grains make a relatively smaller share of total household expenditure. Therefore, dampening of grains prices in rural areas after fuel subsidy was removed have resulted in higher income losses among farm households.

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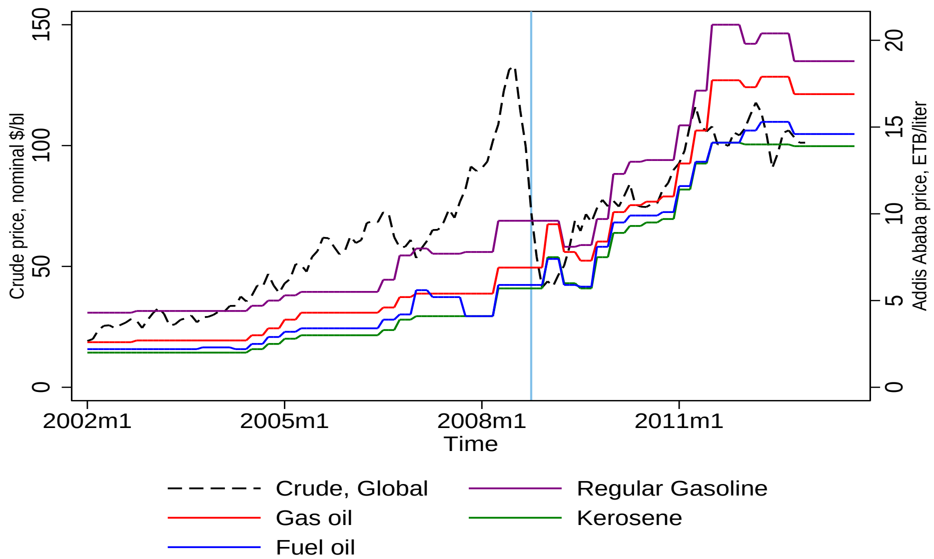
A. Annex

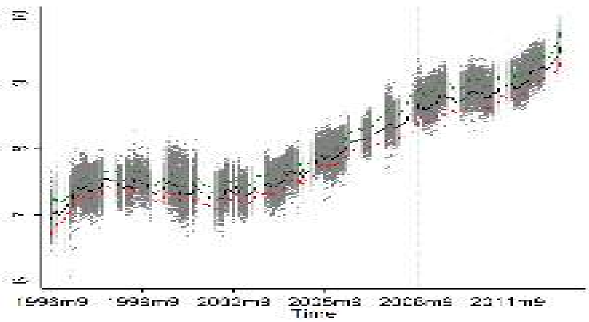
A.1. Commodity markets

Figure A.1: Trends of global average crude oil price and quarterly retail fuel prices in Addis

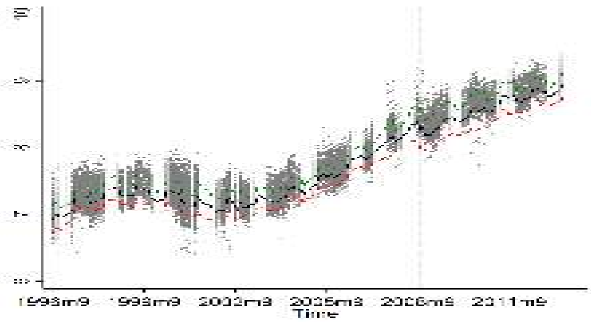


Data Source: National Bank of Ethiopia and
World Bank, GEM (2014)

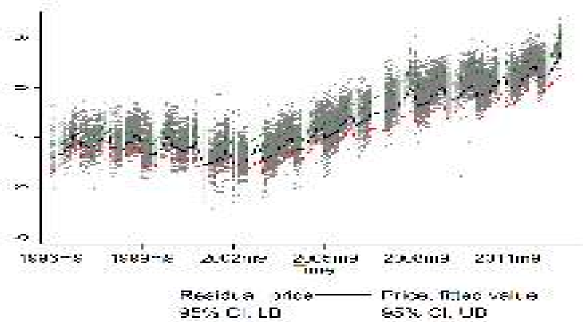
Figure A.2: Impact of subsidy reform on price level, log(ETB/MT)



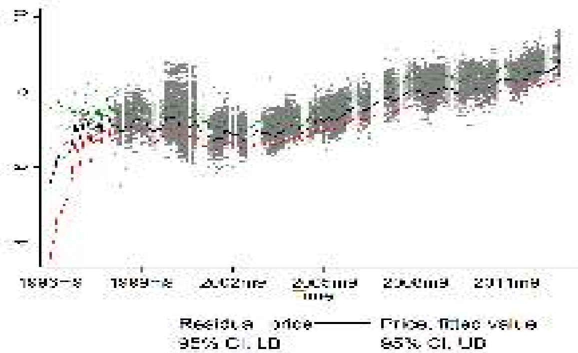
(a) 'Teff'



(b) Wheat

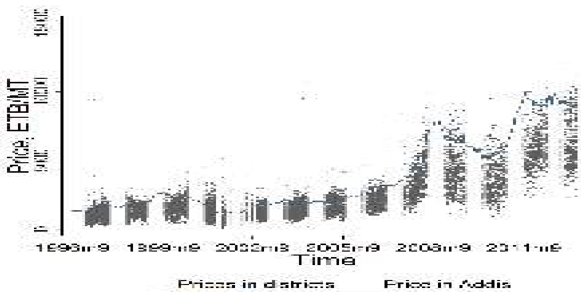


(c) Barley

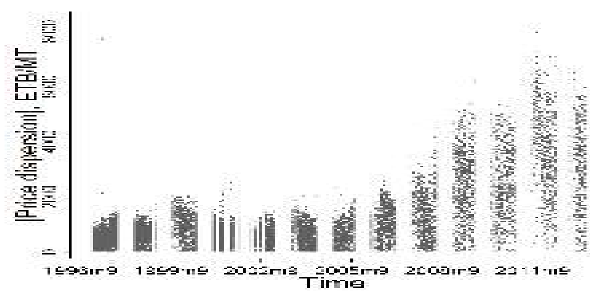


(d) Maize

Figure A.3: Barley price and its dispersion over time (1996–2013)

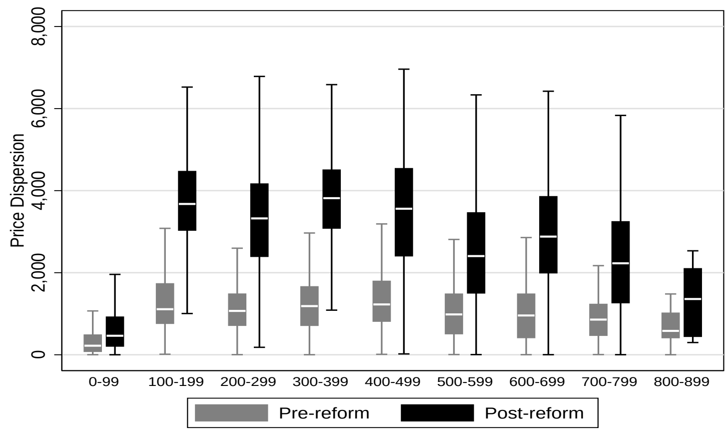


(a) Price



(b) Price dispersion

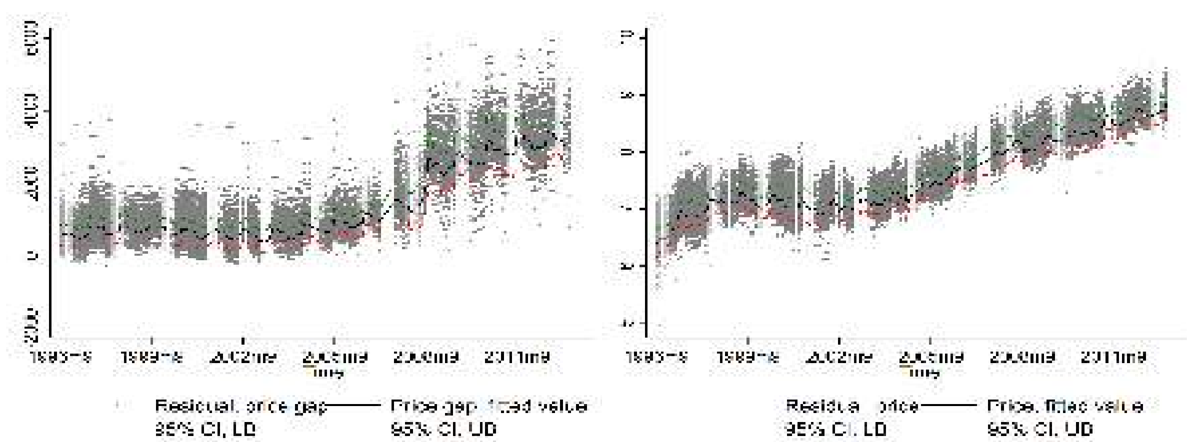
Figure A.4: Differences in price dispersion based on the districts' distances from the capital (x-axis), pre- and post-reform



(a) White barley

Note: Districts are divided into twelve groups based on their distances from Addis, from those within 100 km to those 1100-1200 km away (range of 100km).

Figure A.5: Impact of subsidy reform on barley price and its dispersion, RD result



(a) Price dispersion

(b) Price

Note: Dispersion is measured by absolute value of median Addis price minus prices in other districts.

Figure A.6: Heterogeneity in treatment effect of the reform on barley price dispersion

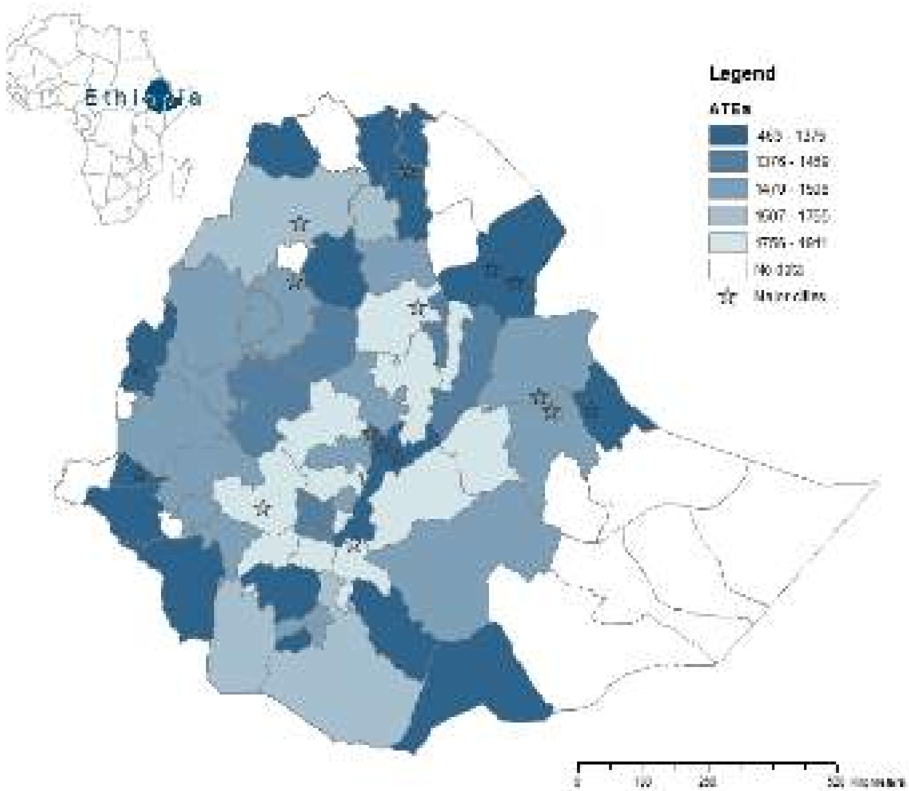


Table A.1: Summary statistics: number of observations, districts with data, mean price (ETB/metric ton) and price gap

Year	Wheat				'Teff'				Maize				Sorghum				Barely			
	N	Districts	Price		N	Districts	Price		N	Districts	Price		N	Districts	Price		N	Districts	Price	
			Level	*Dispersion*			*Level*	*Dispersion*			*Level*	*Dispersion*			*Level*	*Dispersion*			*Level*	*Dispersion*
1996	1763	274	1336	682	893	210	1239	416	258	114	868	346	47	10	1553	322	1593	333	793	611
1997	5566	388	1433	582	3155	343	1315	463	783	184	993	262	168	24	1568	343	4633	441	931	626
1998	5665	327	1699	599	3286	289	1418	467	1105	245	983	354	457	99	1102	529	4306	382	1109	621
1999	3108	201	1799	707	1264	154	1698	442	1407	195	1034	461	1158	117	1138	602	1519	163	1552	774
2000	5364	255	1951	603	3491	264	1708	395	1273	225	1144	390	2929	247	2003	1311	3549	260	1560	692
2001	5370	347	1518	619	3373	336	1242	430	1448	329	709	316	3110	318	1729	1273	3676	345	1131	559
2002	4338	341	1385	657	1852	285	1194	404	1833	338	690	341	2072	244	794	502	2138	282	1022	475
2003	4112	294	1853	623	1805	251	1520	495	1870	301	988	578	2041	221	1139	683	2028	244	1404	544
2004	4331	299	2029	572	1928	239	1550	415	1960	289	1012	411	2475	213	1192	527	2046	242	1447	535
2005	4549	314	2219	607	2076	260	1750	447	2065	296	1182	598	2358	220	1349	666	2093	256	1606	600
2006	4445	310	2967	737	2047	267	2254	637	2096	307	1251	565	2497	215	1500	863	2075	254	1931	772
2007	2601	387	3753	939	1181	318	2872	771	1221	373	1572	798	1320	257	2047	1002	1246	299	2484	1030
2008	4087	305	6165	1435	1749	256	4731	1085	2017	305	3337	1374	2301	224	3869	1499	1871	247	4127	1619
2009	4748	301	7001	2178	2138	253	4656	1609	2195	287	2959	1567	2510	217	3650	2441	2141	238	4084	2176
2010	4888	364	5757	2271	2156	306	4050	1612	2170	334	2106	1646	2454	244	2716	2735	2024	269	3463	2026
2011	4359	302	7085	1814	1854	237	6340	2160	2042	286	3579	2077	2238	194	4010	2153	1674	207	5111	2654
2012	4404	294	10292	2175	1936	248	7082	2209	2133	273	4403	2002	2403	202	5433	2615	1751	219	6336	2518
2013	2443	280	11263	2796	1102	219	6785	2020	1072	233	4310	2235	1283	186	5537	3202	924	186	6078	2613

Note: N stands for number of observation. 'Districts' refers to number of districts/'woredas' that have reported prices in the corresponding year. 'Price' refers to mean price in rural districts. 'Price Dispersion' is the difference in median price (ETB/kg) between Addis and other districts.

Table A.2: Robustness checks with 'balanced' panel, ATE on price dispersion

	(1) Teff	(2) Wheat	(3) Maize	(4) Sorghum	(5) Barley
ATE	1166***	546***	616**	1127***	775***
	(134.7)	(154.5)	(215.2)	(211.7)	(210.8)
Observations	37356	11153	9549	15001	14183

Note: All covariates used in the main regression are controlled for here. The estimate focuses on districts that have more than 75% observation around the reform period (2009–2009), i.e. 'balanced' panel. Standard errors are clustered multi-way (district-year). Multi-way clustered robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

Table A.3: Spatial heterogeneity in price dispersion effects, ATEs over intervals of 100 km driving distance radius from Addis

	(1)	(2)	(3)	(4)	(5)
Distance (in km)	Teff	Wheat	Maize	Sorghum	Barley
0-99	207	-204	-561***	-185	-469*
	(132.7)	(192.1)	(167.9)	(144.6)	(193.4)
100-199	954***	933***	951***	1233***	1911***
	(146.1)	(127.1)	(121.1)	(172.2)	(176.6)
200-299	1319***	972***	1056***	1825***	1467***
	(132.9)	(141.2)	(97.1)	(136.3)	(155.4)
300-399	1369***	842***	1190***	1796***	1760***
	(125.7)	(129.4)	(109.8)	(157.5)	(145.9)
400-499	1461***	1127***	1323***	2150***	1503***
	(130.0)	(154.0)	(103.9)	(177.5)	(164.6)
500-599	985***	717***	1385***	2070***	1372***
	(133.4)	(186.4)	(133.9)	(156.0)	(178.9)
600-699	1044***	812***	945***	1782***	1752***
	(185.9)	(181.8)	(171.4)	(135.6)	(260.1)
700-799	723***	575**	995***	1822***	1141***
	(173.1)	(208.5)	(202.7)	(228.2)	(212.8)
800-899	706***	-698**	771***	1295***	-386
	(150.5)	(265.6)	(141.7)	(183.1)	(316.2)
900-999					
1000-1099			97		
			(136.6)		
1100-1199	3061***		1271***	-425	
	(216.5)		(134.6)	(530.1)	
Observations	66817	31182	26155	26364	36497

Note: (District) Cluster robust standard errors are in parentheses: *** p<0.01, ** p<0.05, * p<0.1. Covariates are commodity grade, MOY FEs, district FEs, border dummy, and fifth order time polynomial.

Table A.4: Impact (ATE) of the reform on national (log) price level, RD result

	Full sample (1996-2013)			Restricted sample (2004-2013)		
	(1)	(2)	(3)	(4)	(5)	(6)
'Teff'	0.16	0.15		0.29	0.27	
	(0.17)	(0.17)		(0.18)	(0.19)	
N	75945	75945		40772	40772	
Wheat	-0.13	-0.15	-0.19	0.05	0.04	-0.01
	(0.14)	(0.14)	(0.15)	(0.16)	(0.16)	(0.20)
N	37153	37153	33134	18111	18111	18111
Maize	-0.09	-0.11	-0.45*	0.03	-0.01	-0.13
	(0.21)	(0.23)	(0.19)	(0.29)	(0.32)	(0.22)
N	28947	28947	16978	18970	18970	12850
Sorghum	-0.02	-0.03	-0.03	0.07	0.05	0.08
	(0.22)	(0.22)	(0.18)	(0.24)	(0.25)	(0.22)
N	33798	33798	33751	21839	21839	21839
Barley	-0.11	-0.13	-0.18	0.06	0.04	0.04
	(0.15)	(0.15)	(0.13)	(0.17)	(0.18)	(0.22)
N	41284	41284	27344	17843	17843	13677
Covariates:						
District FEs & MOY FEs	Yes	No	No	Yes	No	No
District FEs*Season FEs	No	Yes	Yes	No	Yes	Yes
Import/Export	No	No	Yes	No	No	Yes

Note: For the two commonly imported grains (wheat and maize), I control for both import and export volume (in metric tones). For barley and sorghum, only export volume is controlled for as there is little or no import of these items. Data on 'teff' export is not available, and the grain is indigenous to Ethiopia and hence import is not applicable. Additional covariate that is controlled for in all estimates is item grade.

Multi-way (district-year) cluster robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

A.5: Spatial heterogeneity in *price level* effects, ATEs over a range of 100 km driving distance radius from Addis

Distance (in km)	(1) Teff	(2) Wheat	(3) Maize	(4) Sorghum	(5) Barley
0-99	2521***	644	949	2143***	1048
	(704.8)	(548.9)	(552.0)	(602.4)	(556.6)
100-199	-1123***	-1724***	-1253***	-1852***	-2094***
	(189.5)	(193.7)	(173.4)	(219.5)	(204.9)
200-299	-1467***	-1801***	-1429***	-2465***	-1862***
	(167.6)	(200.9)	(119.1)	(174.7)	(178.5)
300-399	-1749***	-1657***	-1566***	-2754***	-2130***
	(162.8)	(211.0)	(119.7)	(185.2)	(171.4)
400-499	-1817***	-1925***	-1652***	-2923***	-1971***
	(170.6)	(210.7)	(110.3)	(200.4)	(191.0)
500-599	-1529***	-1479***	-1731***	-2691***	-1395***
	(196.3)	(226.3)	(136.7)	(170.9)	(228.6)
600-699	-1778***	-1740***	-1270***	-2420***	-1999***
	(182.1)	(218.6)	(175.7)	(184.1)	(309.6)
700-799	-950***	-1126***	-1068***	-2379***	-1250***
	(208.3)	(232.2)	(212.2)	(241.4)	(242.0)
800-899	-838***	-1297***	-986***	-1888***	462
	(151.6)	(392.6)	(170.2)	(330.3)	(528.2)
900-999					
1000-1099			-2362***		
			(209.4)		
1100-1199	-3176***		-2237***	-6113***	
	(214.0)		(244.6)	(495.2)	
Observations	67880	33378	26469	31497	37147

Covariates are commodity grade, MOY FEs, district FEs, border dummy (equal to one if the zone shares boarder with a neighboring country), and fifth order time polynomial.

Table A.6: Impact of the reform on price dispersion: sDID result with standard error clustered at district level

	(1) Teff	(2) Wheat	(3) Maize	(4) Sorghum	(5) Barley
Distance*Post	102.9***	89.9**	98.2***	204.2***	159.2***
	(27.6)	(29.4)	(22.9)	(31.2)	(40.9)
Distance, 100 km	38.3*	-24.9*	23.8*	-1.7	-36.1*
	(16.2)	(12.2)	(12.1)	(20.8)	(15.3)
Post	1147.9***	1166.0***	966.4***	941.3***	1229.0***
	(114.2)	(116.2)	(97.1)	(142.1)	(179.9)
Observations	66817	31182	26155	26364	36497

Note: (District) Clustered robust standard errors in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Covariates included as control variables are commodity grade, year FEs, MOY FEs, and region FEs, border dummy (equal to one if the zone shares boarder with a neighboring country), and the district's distance from the regional capital or another major regional town.

A.2. Welfare Annex

Figure A.7 Share the five grains in food and total household expenditure, and annual energy and transport expenditure, 2004/5

	Share (%) of grains/food exp			**Energy exp (ETB/year)**					
				Urban			*Rural*		
Consumption Quartile	Grains in HH exp	Grains in food exp	Food in HH exp	Kerosene	Transport	Car	Kerosene	Transport	Car
1	32	45	71	20	77	2	7	7	0
2	32	47	69	28	205	10	11	20	0
3	29	45	64	31	299	26	9	33	4
4	17	35	50	32	552	141	14	113	4
National Average	27	42	62	28	340	67	10	42	2

Note: Grains refer to the five grains ('teff, wheat, maize, barley, and sorghum) analyzed in the preceding section. HH and exp refer to household and expenditure respectively. Transportation includes fare for bus, taxi, and trucks. Car refers to monthly household expenditure on car fuel, oil, and grease. Consumption quartile is based on per capita consumption.

Figure A.8 Consumption and production ratios for farm and non-farm households, by per capita consumption quartile

Household Type	Ratios	Consumption Quartile				
		1	2	3	4	Total
Farmer	Production ratio	0.83	0.86	0.84	0.78	0.83
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
.	Consumption ratio	0.37	0.38	0.34	0.27	0.34
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Non-farmer	Production ratio	0.05	0.06	0.06	0.03	0.04
		(0.00)	(0.01)	(0.01)	(0.00)	(0.00)
.	Consumption ratio	0.29	0.29	0.26	0.17	0.23
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Note: A household is classified as 'farm' household if the household head and/or the spouse engage in agriculture as the main economic activity.

Figure A.9 Changes in real incomes (ETB) of farmers and non-farmers due to the reform, by consumption quartile

Household Type	Variables	Consumption Quartile				
		1	2	3	4	Total
Farmers	Income loss (ETB)	-271	-413	-469	-529	-416
		(7.5)	(10.9)	(11.9)	(16.1)	(5.9)
.	% HHs who lost income	75	78	81	77	78
		(0.9)	(0.9)	(0.8)	(1.0)	(0.4)
Non-farmers	Income loss (ETB)	50	49	38	27	37
		(3.9)	(7.0)	(7.6)	(5.7)	(3.2)
.	% HHs who lost income	23	24	25	27	25
		(0.9)	(1.1)	(1.1)	(0.7)	(0.4)

Note: The remaining percentage of households have experienced either no change or positive change in welfare.

Figure A.10 Changes in real incomes (ETB) and percentage of households that have experienced decrease in income, by consumption quartile and region

	Changes in income (ETB)				% HHs who lost income			
Region/Quartile	1	2	3	4	1	2	3	4
Tigray	-60	-144	-151	-155	48	53	48	27
Afar	-100	-120	-131	-91	50	43	41	33
Amhara	-84	-144	-240	-126	49	54	60	34
Oromia	-149	-288	-253	-176	46	55	53	43
Benishangul-Gumuz	-184	-386	-375	-249	49	65	65	41
SNNP	-234	-396	-415	-180	66	73	70	46

Note: The remaining percentage of households have experienced either no change or positive changes in welfare.

A.3. Online Appendix

Table A.11: Impacts (ATEs) of fuel subsidy reform on price dispersion, RD result with standard error clustered at district level

	Full sample (1996-2013)			Restricted sample (2004-2013)		
	(1)	(2)	(3)	(4)	(5)	(6)
'Teff'	1391***	1360***	1364***	1053***	1131***	1082***
	(74.5)	(74.1)	(74.3)	(63.9)	(63.5)	(63.5)
N	74703	74703	74703	40772	40772	40772
Wheat	559***	537***	535***	1023***	1075***	1038***
	(86.1)	(81.4)	(81.2)	(88.6)	(86.7)	(85.0)
N	34838	34838	34838	16500	16500	16500
Barley	732***	746***	736***	1114***	1241***	1109***
	(106.0)	(102.1)	(102.5)	(112.5)	(112.9)	(108.1)
N	40539	40539	40539	17843	17843	17843
Corn	613***	596***	598***	726***	765***	663***
	(51.8)	(50.2)	(50.0)	(55.1)	(54.9)	(52.1)
N	28571	28571	28571	18970	18970	18970
Sorghum	1614***	1446***	1447***	1346***	1402***	1333***
	(115.8)	(111.6)	(111.9)	(105.6)	(108.0)	(103.8)
N	28243	28243	28243	18379	18379	18379
Covariates:						
Item grade	Yes	Yes	Yes	Yes	Yes	Yes
District FEs	No	Yes	Yes	No	Yes	Yes
MOY FEs	No	No	Yes	No	No	Yes

Note: All regressions include fifth-order polynomial of time. Standard errors, which are clustered at district level, are in parentheses: * p<0.05, ** p<0.01, *** p<0.001

Table A.12: RD result, with censored regression

	(1) Teff	(2) Wheat	(3) Maize	(4) Sorghum	(5) Barley
ATE	1189***	460***	545***	1235***	716***
	(17.2)	(22.3)	(20.6)	(31.3)	(26.9)
N	74703	34838	28571	28243	40539

Note: Covariates included as control variables are commodity grade, interaction between season FEs and region FEs, and fifth order time polynomial. Standard errors parentheses: *** p<0.01, ** p<0.05, * p<0.1.

Table A.13: Impacts (ATEs) of fuel subsidy reform on price dispersion, RD result additional robustness checks

	(1)	(2)	(3)	(4)	(5)
	Main Result			Different time-polynomials	
'Teff'	1364***		1372***	1269***	1138***
	(74.3)		(75.0)	(68.1)	(62.2)
N	74703		74703	74703	74703
Wheat	535***	414***	537***	597***	778***
	(81.2)	(80.3)	(82.5)	(77.5)	(79.2)
N	34838	30819	34838	34838	34838
Barley	736***	646***	752***	750***	867***
	(102.5)	(98.8)	(103.6)	(98.0)	(98.6)
N	40539	19804	40539	40539	40539
Corn	598***	620***	610***	598***	666***
	(50.0)	(50.4)	(50.6)	(47.7)	(48.3)
N	28571	28313	28571	28571	28571
Sorghum	1447***	1464***	1453***	1479***	1157***
	(111.9)	(112.3)	(114.3)	(106.7)	(99.0)
N	28243	21253	28243	28243	28243
Covariates:					
Import/Export	No	Yes	No	No	No
MOY FEs * Zone FEs	No	No	Yes	No	No
Degree of *f(time)*	5	5	5	6	7

Note: All covariates in the main specification (i.e. item grade, district FEs, MOY FEs) are also included in the above regressions. Standard errors, clustered at district level, are in parentheses: * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Data on 'teff' export is not available, and the grain is indigenous to Ethiopia and hence import is not applicable.

Table A.14: Spatial heterogeneity in treatment effects on price dispersion: RD on population weighted distance from cities

Distance (in km)	(1) Teff	(2) Wheat	(3) Maize	(4) Sorghum	(5) Barley
0-99	204	-199	-561***	-207	-470*
	(128.9)	(188.5)	(165.1)	(139.9)	(187.2)
100-199	969***	959***	941***	1248***	1945***
	(144.2)	(127.0)	(110.2)	(160.3)	(176.7)
200-299	1319***	896***	1107***	1937***	1452***
	(127.9)	(143.7)	(102.0)	(139.3)	(151.3)
300-399	1392***	981***	1167***	1654***	1757***
	(125.6)	(130.0)	(109.3)	(155.5)	(142.3)
400-499	1397***	940***	1354***	2240***	1410***
	(127.8)	(148.3)	(110.4)	(148.9)	(164.4)
500-599	939***	785***	1354***	2032***	1503***
	(141.3)	(175.9)	(130.5)	(182.5)	(179.3)
600-699	927***	724***	953***	1902***	1567***
	(175.5)	(181.4)	(166.0)	(128.9)	(240.2)
700-799	708***	487*	890***	1504***	916**
	(201.9)	(216.5)	(234.8)	(206.7)	(341.8)
800-899	765***	-680*	886***	1164***	76
	(92.8)	(264.8)	(172.7)	(181.9)	(200.1)
900-999					
1000-1099			111		
			(146.4)		
1100-1199	3060***		1283***	-434	
	(200.3)		(135.6)	(451.9)	
Observations	66817	31182	26155	26364	36497

Note: Covariates are commodity grade, interaction between district FEs and season FEs, border dummy (equal to one if the zone shares boarder with a neighboring country), and fifth order time polynomial. Multi-way cluster (year and district) robust standard errors (see Cameron et al. (2008)) in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

Table A.15: sDID on population weighted distance from Addis and the major regional city

	(1) Teff	(2) Wheat	(3) Maize	(4) Sorghum	(5) Barley
Distance*Post	102.9**	89.9*	98.2***	204.2***	159.2**
	(38.4)	(43.3)	(29.4)	(35.4)	(55.2)
Post	1147.9***	1166.0***	966.4***	941.3***	1229.0***
	(158.9)	(152.4)	(118.9)	(161.0)	(180.8)
Distance, 100km	38.3*	-24.9	23.8	-1.7	-36.1
	(19.3)	(15.7)	(14.7)	(29.8)	(23.4)
Observations	66817	31182	26155	26364	36497

Note: Covariates included as control variables are commodity grade, and interaction between season FEs and region FEs. Multi-way cluster (year and district) robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

Table A.16: sDID result, with censored regression

	(1) Teff	(2) Wheat	(3) Maize	(4) Sorghum	(5) Barley
Distance*Post	100.1***	113.7***	97.0***	212.6***	206.5***
	(2.9)	(4.0)	(4.3)	(4.6)	(4.7)
Post	1035.1***	952.1***	882.2***	761.0***	903.4***
	(12.3)	(14.3)	(19.0)	(20.3)	(18.5)
Distance, 100km	22.9*	-33.0***	37.7***	18.6	-59.5***
	(11.5)	(9.5)	(11.2)	(19.8)	(10.4)
Observations	66817	31182	26155	26364	36497

Note: Covariates included as control variables are commodity grade, interaction between season FEs and region FEs, border dummy and fifth order time polynomial. Standard errors parentheses: *** p<0.01, ** p<0.05, * p<0.1.