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REGULAR ARTICLE

# “Cursed is the ground because of you”:

## The impact of culture, religion, and ethnicity on the adoption of fertilisers in rural Ethiopia

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**Abstract**
This paper analyses culture as a determinant of technology adoption in a developing country. While the literature discusses the influence of culture upon economic growth, little attention has been paid to the mechanisms at the micro level. Therefore, we postulate that culture plays a crucial role in hindering or fostering the diffusion of innovation, a key trigger of the engine of growth. This empirical study uses the Ethiopia Rural Household Survey to disentangle between individual cultural traits, namely, ethnicity and religion, and the cultural homogeneity of the environment as co-determinants of fertiliser adoption. To examine our hypotheses, we apply a multivariate survival model for clustered and correlated observations to account for time and location effects. The results reveal significant differences in the probability of adopting fertiliser among cultural groups. Moreover, habits and social norms, proxied by ethnicity, provide a better explanation for the role of culture, than religious beliefs, as usually posited in the literature. Also, the cultural environment turns out tobe a decisive trigger. The probability of adoption is higher in rural societies with a homogeneous ethnic environment but distinct religious variety.

**Keywords** Adoption · Diffusion · Innovation · Culture · Frailty models · Ethiopia

**JEL Classification** O13 · O33 · Q12 · Q16 · Z1

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## 1 Introduction

Culture is the foundation of human behaviour. Social norms and beliefs taught during up-bringing, adapted to or fortified by the environmental context and transferred to the next generation are key to the differentiation of cultures around the globe. Over the centuries, cultures have adjusted to local and economic conditions (Landes 1998). Nevertheless, our progressively industrialised world reveals enormous gaps in economic welfare, and although many economies are in the process of catching up, this process is sensitive to disruption. Aiming to understand the origins of the divergence in development paths, we examine culture as a determinant of economic performance.

Thus far, most research has analysed the relation between culture and trade or culture and institutions to explain and verify the influence of culture on economic outcomes. These approaches run the risk of identifying spurious relations, as it is a difficult empirical exercise to disentangle economic growth from simultaneous social and cultural development. We thus suggest taking a micro perspective, which can shed light on the underlying mechanisms that connect cultural background and growth.

Therefore, this paper investigates the link between culture and innovation, which is a key trigger for economic growth. Moreover, as we are considering the case of a developing country, we focus on the adoption of existing innovation, as it is considered a decisive comparative advantage in initiating the process of catching up.

With regard to adopting innovation, chemical fertilisers are an advantageous choice because they bear the potential to increase agricultural productivity and thus fight malnutrition. Additionally, an increase in productivity in rural areas is often a first necessary step on the path to development. To test our hypothesis we use data on fertiliser adoption in Ethiopia, a country notorious for famines, malnutrition and the vulnerability of its socio-economic system (Block and Webb 2001; Rashid et al. 2013; IFPRI 2014). Although the use of fertiliser was promoted as early on as the military Derg Regime (1974 - 1991) already and application rates increased by 180 percent between 1993 and 2005 (UNDP 2010), fertiliser diffusion remains insufficient in rural Ethiopia (Rashid et al. 2013). Furthermore, the diffusion of chemical fertilizers in Ethiopian Peasant Associations seems to be an ideal case study, since it occurs in rural villages with a high degree of both religious and ethnic heterogeneity, it does not involve technical trade-offs, and it exhibits low cost of adoption (Beretta et al. 2018). Finally, agricultural practices in early-stages developing countries root in ancient cultural habits and, therefore, they are a suitable test bed to look at the impact of culture on adoption of innovations (Dessalegn 1984; Johnson 1972; MacPherson and Jackson 1975).

A large body of literature on development and innovation has offered general explanations for the adoption and diffusion of agricultural innovation (Feder et al. 1985; Sunding and Zilberman 2001; Knowler and Bradshaw 2007; Duflo et al. 2011), and many scholars have focused on the specific case of Ethiopia (Croppenstedt et al. 2003; Asfaw and Admassie 2004; Dadi et al. 2004; Weir and Knight 2004; Carlsson et al. 2005; Dercon and Christiaensen 2011; Krishnan and Patnam 2014). However, there are no studies of cross-cultural dissimilarities as a determinant of the adoption of fertiliser.

In the subsequent sections, we review the literature and suggest testable hypotheses. We then introduce the dataset and present the empirical results. Discussion and conclusions follow.

## 2 Literature

In this paper, the discussion regarding the influence of culture is very much informed by Guiso et al. (2006), who define culture as “[...] customary beliefs and values that ethnic, religious, and social groups transmit fairly unchanged from generation to generation”. It is worth emphasizing that Guiso et al. (2006) consider religion as one element among others characterizing the concept of culture, while the enduring debate surrounding cultural and economic outcomes is rooted in the original controversy regarding the role of religion based on the opposing views of Marx and Weber.

Marx (1844 [1970]) generally understood religion as man-made and viewed religion as being shaped by economic processes over time rather than the reverse. In contrast, Weber (1905 [2001]) suggested that the Protestant religion presented a stronger fit with capitalism than the Catholic religion and claimed religion had an independent influence on society (Weber 1905 [2001]). These opposing views, however, shared a common focus on the interplay between culture and economic performance at the macro level. Since then, the literature has retained this unit of analysis and has mainly explained the impact of cross-cultural differences upon economic development by investigating macro variables such as institutions and trade.

In line with Weber’s claim, Grier (1997) finds strong support for a positive relation between the Protestant religion and economic growth in Latin America. Nevertheless, Protestantism does not explain the prevailing gap between former colonies of Protestant European countries in Latin America. Noland (2005) empirically reveals a general impact of religion on economic performance in a cross-country and intra-country analysis but does not find robust patterns for single religious denominations. Pryor (2007) hypothesises, like Weber, that culture plays a preeminent role and finds that in OECD countries, the effect of cultural systems on the economy is stronger than the reverse. Additionally, Luttmer and Singhal (2011) observe a persistent influence of culture on individual preferences, i.e. preferences are determined by country of birth and persist across generations even after emigration. Hence, culture changes only slowly over time as traditional values remain fairly time-consistent, and countries will thus not converge into one world culture (Inglehart and Baker 2000).

Culture can also influence trade by reducing or creating barriers. Sharing a common language and culture reduces problems of misunderstanding and encourages trust (Lazear 1999). However, while most religions seem to support international trade, Jewish, Islamic and Roman Catholic cultures seem to have either no effect or a negative one on bilateral trade between members of the same religion (Lewer and Van den Berg 2007).

Greif (1994) regards the organization of a society as a reflection of culture. For instance, developed countries harbour individualist societies, while collectivist thinking prevails in developing countries. The examination of Maghrebi and Genoese traders in the eleventh century suggests that cultural beliefs generate different institutional systems and hence, different growth trajectories (Greif 1994; 1998). Gorodnichenko and Roland (2010, 2011) also distinguish between individualist and collectivist societies. They find a positive relationship between long-term growth and individualism and consider the individualist-collectivist distinction as the essential determinant explaining differences in economic development.

A second stream in the literature focuses on the role of institutions as the factor mediating between culture and economic development. According to La Porta et al. (1999), the quality of government is generally higher in countries with high ethnolinguistic homogeneity, as is the case in rich Protestant countries that apply common law. In a cross-country study, Tabellini (2008) suggests that the functioning of institutions depends on how extensively cultural values, in particular respect and trust, are historically shared within a society. As values and norms are time-persistent and mainly vertically transmitted, they reflect past institutional settings. Descendants of individuals who experience an environment characterised by low levels of social respect and trust usually reduce the institutional performance of their country compared with individuals from societies with a long-standing tradition of generalized morality. These dynamics may hint towards either a vicious or virtuous circle for economic development. The reciprocal relation between institutional performance and social values may be a boon or bane as current economic development reflects the historical performance of institutions (Acemoglu et al. 2001; Ang 2013).

Guiso et al. (2003) confirm that values and norms that foster economic development are on average positively correlated with religion. They suggest that religious participation and denomination are different sides of the same coin and may reveal contradictory associations with norms within the same religion. Therefore, a ranking in the spirit of Weber is not possible as the impact of a religion on norms may depend on which side of the coin one observes (Guiso et al. 2003). Hence, self-declared affiliation with a religion does not necessarily account for the strength of individual religious beliefs. Blum and Dudley (2001) find that active participation in religious networks rather than individual religious affiliation has a crucial effect on economic prosperity. Religious beliefs are also positively associated with economic growth, although church attendance has a negative relationship with economic growth when the level of belief is kept constant (Barro and McCleary 2003). Church attendance thus does not enhance the intensity of belief as a driver of growth (Barro and McCleary 2003). We suggest the differing results of Barro and McCleary (2003) and Blum and Dudley (2001) are due to variation in levels of individual freedom, i.e. control versus obedience (Tabellini 2010). Whereas active participation in religious networks is based on intrinsic incentives, church attendance may proxy pressure or willingness to conform to family or environmental norms without necessarily being convinced of the beliefs.

The literature cited above adheres to the original attempt to measure the link between culture and growth at the macro level. We suggest that it may be difficult to disentangle the process of socio-cultural development and growth at this level of analysis. More recently, the vast body of literature on experimental economics has attempted to link culture and economic outcome. For instance, cross-cultural experiments by Henrich et al. (2001) propose that individual economic behaviour during experiments depends on comparable situations in daily life. In addition, the understanding of fairness differs between cultural groups (Henrich 2000; Jakiela 2011), and cross-cultural variations in risk preferences can partially be explained by particular religions (Miller 2000; Liu 2010). On the contrary, cross-cultural differences vanish if experiments are repeated in different locations within a country, as the variation appears to be captured by the location of the experiment and not by country or culture (Oosterbeek et al. 2004). In general experimental evidence on the impact of religion on economic outcome has been largely inconclusive. Hoffmann (2013) reviewed the literature and concludes the there is no effect of a specific religion on trust, altruism (Chuah et al. 2007, among others; Shariff and Norenzayan 2007; Stenman et al. 2006), and cooperation behaviors which are considered the main channels which might link religion with economic outcome. Also parametric exercises discussing the impact of religion on individual preferences on risk and times do not lead to any significance results (Benjamin et al. 2016). However, with few notable exceptions (Stenman et al. 2006), most of the experiments are carried among students in western countries, possibly less affected by traditional religious believes, and they focus on the few typical mechanisms considered in experimental works.

Therefore, we still believe, that cultural variety, partly explained by religion, might play a role, albeit via a new specific mechanism, specified in the next section. We postulate that a micro perspective provides a promising path, as it allows the examination of the underlying mechanisms linking culture and growth, such as group behaviour, risk preference or diffusion of knowledge. More specifically, we aim to explore whether culture affects the process of adoption of innovative technology, a key element to fostering growth in developing countries. While standard economic theories have neglected the link between culture and adoption of innovation as an explanation of the relationship between culture and growth, marketing research has showed fundamental cross-country differences in the diffusion of new products associated with the national culture. For instance, Singh (2006) or Erumban and De Jong (2006), based on the diffusion frameworks of Bass (1969) and Rogers (2003), apply the cultural dimensions defined by Hofstede (1983) and Hofstede et al. (1991). The importance of culture on national technology diffusion trajectories is also revealed by Green and Langeard (1975), Gertler (1995) and Gatignon et al. (1989).

Steers et al. (2008) argue that the adoption of innovation does not occur in a "cultural vacuum"[1]. Hence, considering social norms of the environment is essential to properly understand the adoption decision. A review of diffusion research provides a number of examples such as the poor diffusion of health technology in Peru (Rogers 2003), the rapid diffusion of ICT in Korea (Lee and Ungson 2008), ethanol adoption in Brazil (Nardon and Aten 2008) or the diffusion of portable music

[1] To use the analogy of Elihu Katz: "It is as unthinkable to study diffusion without some knowledge of the social structures in which potential adopters are located as it is to study blood circulation without adequate knowledge of the veins and arteries" (Katz 1961).

players in Western societies versus Japan (Trompenaars and Hampden-Turner 1998). A closer look at these examples reveals interesting patterns. Rogers (2003) finds that the rejection of a health-supporting technological innovation in a Peruvian village can be explained by the incompatibility of the technology with the prevailing social norms and values of the local society. Lee and Ungson (2008) find Korea's collectivist national culture with its distinctive personal relationships and networks to be a main driver of ICT diffusion in Korea. Analysing ethanol adoption in Brazil, Nardon and Aten (2008) emphasize the crucial importance of understanding the process and not only the result of human behaviour, as the underlying logic in how to approach a problem culturally differs in ways that may not be captured solely by values and norms. Lastly, Trompenaars and Hampden-Turner (1998) examine varying cross-national incentives to adopting portable music players in developed countries. While Western societies adopt music players as an expression of their desire for isolation and independence, the Japanese use music players to avoid disturbing their environment (Trompenaars and Hampden-Turner 1998). Similarly, Japanese culture prioritizes interpersonal communication over impersonal communication that is favoured in some European countries (Hall and Hall 1987). Although communication channels differ among cultures, their main purpose is to raise awareness and to reduce uncertainty and risk with regard to adoption decisions (Midgley and Dowling 1978; Mahajan et al. 1990). However, the perception of risk among societies differs as well. Weber and Hsee (1998) explain these differences using the "cushion hypothesis", i.e. individuals in collectivist societies have a higher probability of receiving financial support from their network and hence, are less risk averse than individuals in individualistic societies. They evidence their hypothesis by conducting a country comparison between the U.S., China, Germany and Poland (Weber and Hsee 1998), as well as between China and the U.S. (Hsee and Weber 1999).

### 2.1 Hypotheses

It is to noticed that the literature managed to highlight an effect of culture on both growth at the macro level and adoption at the micro-level. However, it fails in identifying mechanisms, which are suggested only ex-post as possible explanation. In the next section we surmise two hypotheses. First, we test whether in our sample we can find a significant difference in the propensity to adopt in different cultural segment. Secondly, we test the hypothesis that the triggering mechanism is associated with the information flow within a community.

- *H1: Culture, proxied by religion and ethnicity, affects the individual decision to adopt chemical fertilisers in rural Ethiopia.*

Although we focus on the household level, we cannot dismiss the role of the surrounding society, where values and norms are embedded (Magnan et al. 2015). In our context, the focal characteristics of the social environment are the fragmentation by ethnic and religious denomination, i.e. the structure of the society, and the attitude of individuals to link with social peers. Hereby, the notion of homophilic systems expresses the preference of its members to link with others that share similar values, while individuals in heterophilic systems prefer to interact with those that are different in terms of norms, attitudes, language etc. (Rogers 2003). Highly homophilic systems allow ideas to be communicated more quickly between peers and spur economic development (Munshi 2004; Montalvo and Reynal-Querol 2005). In turn, homophilic systems may cause a shortage of new knowledge due to missing external information (Munshi 2004). This quandary is also known as "the strength of weak ties" described by Granovetter (1973). In order to overcome the information gap but retain the advantageous structure, homophilic systems have to admit a certain level of heterophily among their members.

Since we cannot observe households attitudes towards other members of the local society, we assume homophilic behaviour in terms of religion and ethnicity. Our assumption relies on the observation that heterogeneous societies have less social interaction (Alesina and Ferrara 2000) and the preference of Ethiopian farmers to trade within ethnic and religious ties (Abebe et al. 2016). Under the assumption of homophilic behaviour, we proxy the social environment by the ethnic fractionalization index that expresses the probability that two randomly drawn individuals do not belong to the same ethnic group (Alesina et al. 2003; Alesina and Ferrara 2005). The fractionalization index provides a measure of diversity that can be interpreted twofold. On the one hand, higher levels of diversity reduces the number of ethnic equals within groups and hence limits the available range of information for each group as they are assumed to not mix socially. On the other hand, higher levels of ethnic fractionalization potentially expand the number of diverse external communication channels and increases the range of information. Thus highly diversified societies could face situations where the joint pool of information is large but the access to it is limited due to ethnic blinkers. We thus suggest that fractionalization, as defined in the next section, can hinder the diffusion of knowledge and *ceteris paribus* slow down a process of adoption. Beretta et al. (2018) corroborates this hypothesis and show with a simulation model that actual diffusion curve of adoption of fertilizers can be replicated only under the assumption of some degree of homophilic behavior.

- *H2: The degree of fractionalization of the rural society affects the adoption of chemical fertiliser in rural Ethiopia.*

In the process of hypothesis testing, we account for a number of controls suggested by the literature on adoption. The main determinant of adoption is generally the perceived profitability or utility depending on prices and on perceived risk and uncertainty. While prices are crucial at any stage of the diffusion process, risk and uncertainty may be partially reduced for imitators[2] due to communication (Havens and Rogers 1961; Mansfield 1961) as well as to observability and trialability[3] of the innovation over time (Rogers 2003). In the context of a developing country the seminal work of Feder et al. (1985) points out barriers to adoption such as (1) lack of human capital to apply the innovation, e. g. illiterate farmers may be unable to use an

[2] In contradiction to Bass (1969), an imitator is simply a time-distinct follower of the innovator (first adopter), independent of the impacting factor.

[3] If the performance of the innovative technology is vulnerable to environmental conditions, i.e. weather extremes etc., the reduction of risk by observability and trialability may be negligible.

innovative farm tool due to their missing ability to read the instructions of the manual; (2) lack of labour force related to farm work, e. g. farmers miss support in process of tilling, planting or harvesting; (3) credit and supply constraints to purchase a new technology; and (4) tenure, as the decision to adopt agricultural innovations depends on the ownership status over territory which is also a dimension of uncertainty. Furthermore, David (1966) identifies farm size as a crucial factor for the adoption of an agricultural innovation as for example the acquisition of a tractor or reaping machine requires a minimum size to pay off and is unattractive to adopt for farmers with plot sizes below the minimum threshold. Moreover, Griliches (1957) demonstrates in his seminal work on hybrid corn that the diffusion of innovations are characterised by logistic or s-shaped curves and therefore the aggregate adoption level influences potential adopters in their adoption decision.

Finally, earlier works on fertiliser diffusion in Ethiopia show that (1) beside prices the distance to markets and oxen ownership are crucial determinants (Dadi et al. 2004); (2) extension agents are important to initialize the diffusion process in a community but the experience of neighbours becomes more important at a later stage of the diffusion curve (Krishnan and Patnam 2014); (3) education of farmers is crucial for the adoption in the early stage of diffusion and for the decision making process within households (Asfaw and Admassie 2004; Weir and Knight 2004); (4) Ethiopian farmers require credits as households cash resources are insufficient to cover fertiliser expenses and inputs have to fit the needs of adopters to be perceived profitable (Croppenstedt et al. 2003; Carlsson et al. 2005); and (5) farmer avoid investment in technologies that are vulnerable to shocks (Croppenstedt et al. 2003; Dercon and Christiaensen 2011)[4]. There are many other possible non-observable factors which might impinge on the adoption decision such as for instance soil quality or diffusion policies. While the next Section describes the data, Section 4 discusses how we are able to take into account the non-observable heterogeneity at least at the PA level, with the use of a frailty model.

## 3 Data

### 3.1 Ethiopia rural household survey

The investigation of culture as a determinant of innovation adoption is conducted through an analysis of the Ethiopia Rural Household Survey (ERHS). Initially, the ERHS was set up to examine adjustments of household behaviour in the aftermath of the notorious Ethiopian famine of the mid-1980s. The data set thus offers rich information concerning household characteristics as well as topics relating to agriculture, health and women's activities. We focus on the data collected between 1994

[4] These works use the same data, i.e. ERHS, but apply partially different rounds. None of them exploits the complete time frame of the ERHS with respect to fertiliser diffusion.

and 2009. The ERHS surveys 1,477 households over six rounds,[5] adding up to 8,332 observations. Over this period, 200 households exit the survey due to death or migration. Households have also been asked to recall the introduction of agriculture inputs and we are thus able to register time of adoption of chemical fertilizers back in time up to 1958. All in all, although we do not have data on the last decade, we are able to exploit 50 years of variation in adoption choices.

The households are located in 15 Peasant Associations (PAs), mainly situated on the central north-south axis of Ethiopia.[6] The geographic coverage of the ERHS allows to capture eleven ethnic and six religious affiliations as well as a variety of different agricultural systems (Dercon and Hoddinott 2011). Consequently, we cover the main ethnic and religious groups of the highly culturally diverse Ethiopian society.[7]

Differences in farming systems are due to variability in environmental conditions (access to water, deforestation, etc.) and availability of agricultural tools. Hence, the cultivation of staple foods and potential usage of fertiliser differs among the PAs. In general, PAs with high soil fertility have less urgency to employ fertiliser. This is equally true for farmers focusing on climate resistant crops such as enset. Nevertheless, according to the narrative PA studies provided in the ERHS, all PAs are facing a vicious circle of rising population and scarcity of land. Soil fertility decreases due to ongoing deforestation and a lack of fallow land. Additionally, the prices of chemical fertiliser (DAP and Urea) have dramatically increased since 1994 and are thus unaffordable for the majority of farmers. Hence, farmers shift (back) to organic fertiliser such as manure. Aside from high prices, supply shortages and lack of access to loans are important obstacles to acquiring fertiliser. Interestingly, the peasants of two PAs are generally unwilling to adopt chemical fertiliser due to mistrust of its effects or to a reluctance to accept the necessity of stopping soil depletion and erosion.

The data cover a long time span, in which Ethiopia experienced various national institutional settings with different agricultural policies. Extensive policy intervention in agriculture began with the third Five Years Development Plan (1968-73) and never stops until nowadays (Alemu et al. 2002). In the post 1974 period, policies pushed for the creation of cooperative and Peasant Associations and the widespread use of extension agents to advertise the benefits of chemical fertilizers (Dessalegn 1984; Jordan and Guerzoni 2020). The exposure to such policies varies greatly across villages depending on their proximity to larger cities, commercial roads, and the presence of war, especially in the northern area in the Mengistu' Socialist period (Pausewang and et al. 1983). Thus, the policy framework might have influenced the variability of adoption decisions along two dimensions both across villages and overtime. In the methodological session we discuss how we deal empirically with village-specific and time-dependent unobserved heterogeneity.

[5] We combined the 1994a and 1994b rounds into one round. For the sake of clarity, we used round 1994a to extract the baseline characteristics of the households, while round 1994b served to add missing variables or time-dependent information. Thus, this analysis includes six instead of seven rounds, namely 1994, 1995, 1997, 1999, 2004 and 2009.

[6] The geographic distribution of the PAs is available in Appendix Fig. 7.

[7] Over 80 ethnic groups and subgroups exist in Ethiopia (Census 2007). The ethnics surveyed in the ERHS account for three-quarters of the main Ethiopian ethnics.

### 3.2 Descriptives

By the end of the survey period, 72.51% (1,071 out of 1,477) of the households had adopted fertiliser.[8] The survey is heavily left-truncated as 679 households adopted chemical fertiliser before 1994. By 2009, 406 households had still not adopted fertiliser, of which 120 are right censored due to migration or extinction prior to the last round.

The total fertiliser diffusion process depicted in Fig. 3 is characterized by a stylized S-shaped diffusion curve with low rates of adoption upon launch and close to the saturation point, and a higher rate of adoption in between. Figure 1 displays approximately S-shaped diffusion curves for all PAs but reveals large differences in launch time and speed of the diffusion processes. The first adoptions occurred in Trirufe Ketchema and Sirba na Goditi, and after adoption their curves climb at a moderate rate. Interestingly, the first adoptions in Yetmen and Koro Degaga lag approximately twenty years behind the very first adoptions, yet Yetmen and Koro Degaga's rate of adoption takes off quickly and attains a level similar to that of the very first adoptions. The only PA arriving at a 100% rate of diffusion is Aze Deboa, where all peasants adopted even before the first adoption had taken place in Adado or Imdibir. Moreover, the combination of Figs. 1 and 2 suggests a lack of knowledge or information spillover from country level to PA level, as the amount of time until fertiliser diffusion passes the 10% threshold is no lower for late bloomers such as Adado and Imdibir than it is for the early adopters, although the national diffusion of fertiliser has reached a significantly higher level by that time (Fig. 3).

Plotting diffusion curves for ethnic and religious groups reveals a similar picture (Fig. 4). In line with Weber's theory, Protestants perform slightly better than Catholics, though both are surpassed by Orthodox Christians and Muslims, which together comprise the first adopters and reach the highest levels of diffusion. Of the ethnic groups Gedeo and Gurage people seem to be relatively reluctant to adopt, whereas all Kembata as well as the four followers of the "Other" group adopt.

Comparing the diffusion curves of ethnic groups and religions with the PAs curves, it appears that certain ethnic and religious groups are concentrated in certain PAs. Indeed, all but one household in Aze Deboa are Protestants (one Catholic) and belong to the Kembata group, while only four Kembata households live outside Aze Deboa.

Recalling the thoughts of Granovetter (1973) and the notion of homophilic and heterophilic systems, we represent diversity within a PA by using the fractionalization index for ethnicity and religion, separately. The fractionalization index is defined as

$$Frac = 1 - \sum_{i=1}^{n} s_i^2 \tag{1}$$

[8] For the purposes of this study, adoption has taken place once a household has confirmed the usage or the purchase of fertiliser. Nevertheless, we are aware that the application of fertiliser may fluctuate over time and is not necessarily persistent after the first usage (Duflo et al. 2011; Dercon and Christiaensen 2011; Suri 2011).

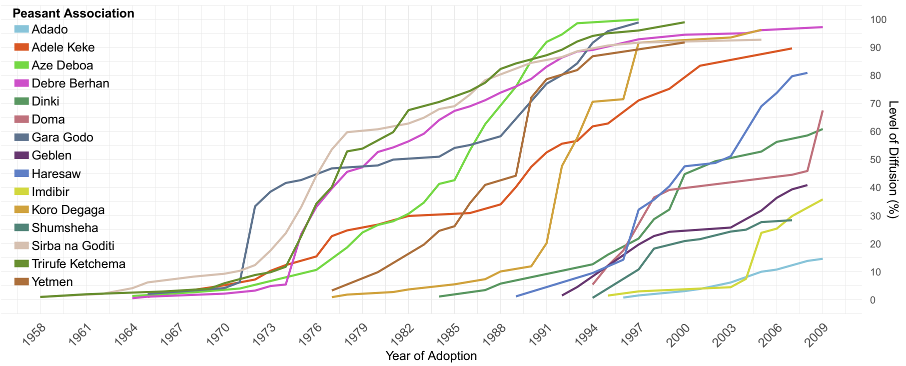


**Fig. 1** Fertiliser diffusion in 15 Peasant Associations between 1958 and 2009. Source: Author’s calculations based on ERHS

with the sum of the quadratic share of each *n* different religious or ethnic groups in a PA. The index ranges from 0 to 1, with 0 presenting an entirely homogeneous society and 1 the theoretical extreme case when each individual belongs to a different cultural group.

The fractionalization indices in Fig. 5 show two perfectly homogenous PAs, namely Yetmen and Shumsheha, with a single religion and a single ethnicity shared by all households. In most cases, the fractionalization index for ethnicity is lower than for religion, and a multiplicity of religions in the same PA is not a rarity. Interestingly, the first adoptions took place in ethnically more diverse PAs, yet the fastest diffusion occurs in PAs comprising a single ethnic group.

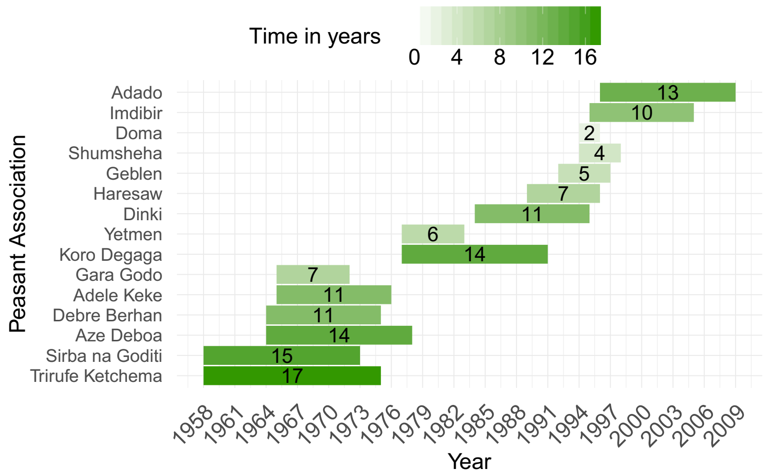


**Fig. 2** Speed of diffusion. Figure 2 presents the first year fertiliser was adopted in each village and the length of time to achieve a diffusion level of 14 %, which nearly depicts the transition from *early adopter* to *early majority* diffusion stage and implies a reasonable awareness about the technology among the local society (Rogers 2003). Source: Author’s calculations based on ERHS

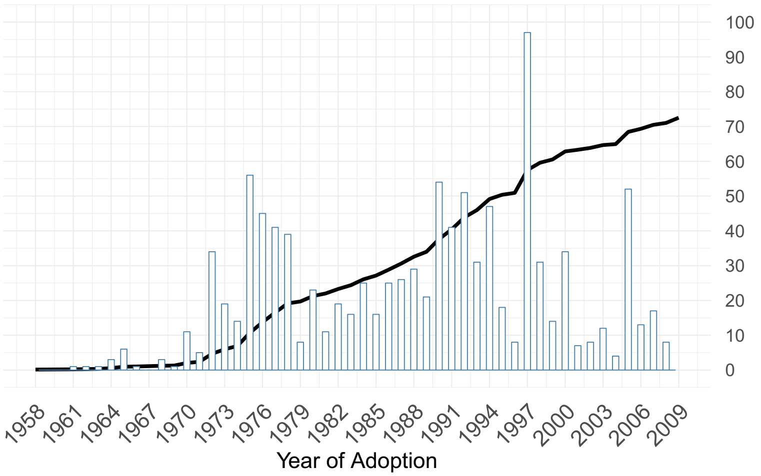


**Fig. 3** Total fertiliser diffusion. The black line in Fig. 3 presents the process of total fertiliser diffusion in the Ethiopian villages and the blue framed bars correspond to the total number of adoptions per year. The y-axis depicts fertiliser diffusion in percentage and the adoptions per year in absolute numbers. Source: Author's calculations based on ERHS

The right side of Fig. 5 shows the co-occurence of specific ethnicities and religions. For instance, Argoba people are all Muslim. The two ruling ethnic groups in Ethiopia are mainly associated with Orthodox Christianity and Islam. However, Fig. 5 shows not only that there is a variability in ethnicity and religious affiliation but also that ethnic groups are associated with more than one religion apart from the Argoba people.

Aside from similarity in cultural backgrounds, we check for the stratification of different cultures within PAs. Specifically, we verify whether an individual is affiliated with a religion or an ethnicity that accounts for the majority of the PA. Under the assumption that major ethnic or religious groups set norms and habits in a rural society, affiliation with the majority may hinder adoption due to public pressure to comply with prevailing norms if norms are inimical towards innovation. In turn, members of minorities may be more receptive to rejecting inimical norms, as they

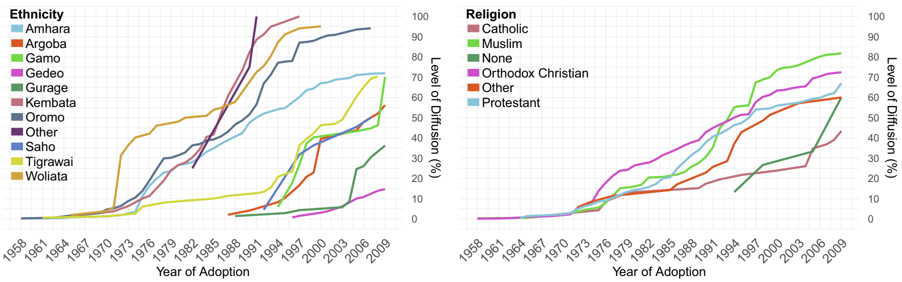


**Fig. 4** Fertiliser diffusion by ethnicity and religion between 1958 and 2009. Source: Author's calculations based on ERHS

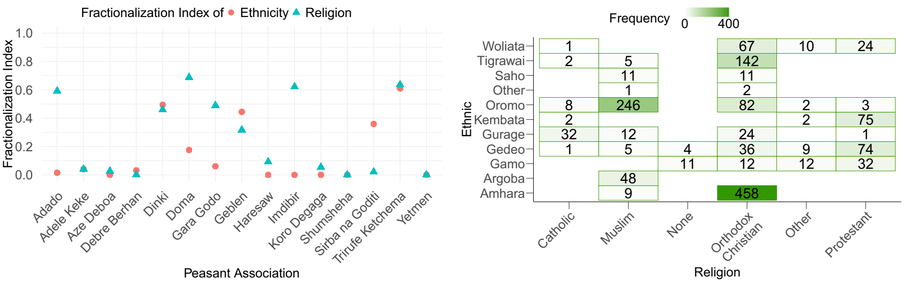


**Fig. 5** Cultural diversity and composition. Source: Author's calculations based on ERHS. The graph on the left-hand side of Fig. 5 presents the ethnic and religious fractionalization in each Peasant Association. Low values of the fractionalization index indicate homogeneity while higher values signal a more pronounced cultural diversity in the local society. In addition, the right-hand side graph reveals the extent of religious co-occurrence within ethnic groups

may not feel under public pressure to obey them (McEachern and Hanson 2008; Platteau 2009). Complementing the fractionalization indices, the empirical model accounts for the issue with an ethnic and religious majority measure.

Cultural variables aside, we account for both household specific and village specific variables such as farm size, oxen ownership, literacy, distance to market and the level of fertiliser diffusion within each Peasant Association [9]. Data have some limitation. Data pre-1994 are derived from answer in 2004, under the assumption that household religion and ethnicity did not change over time: among others, Wink and Dillon (2002) and Sherkat and Wilson (1995) show, that even in Western countries, while an increase in spirituality in adult life is very likely, apostasy and religion switching rarely occur.

## 4 Methodology

### 4.1 The model

In order to exploit the dynamics of diffusion as well as the time dependent structure of many variables of the ERHS, we choose a duration analysis to investigate cross-cultural dissimilarity in fertiliser adoption. Duration analysis allows us to address clustered time to event data and enables us to identify determinants that have a significant influence on time to event. Duration analysis can be used to investigate the adoption of innovations as seen in Hannan and McDowell (1984), Hannan and McDowell (1987), Karshenas and Stoneman (1993), Carletto et al. (1999), Baptista (2000), Carter et al. (2001), Burton et al. (2003), and Dadi et al. (2004) and Jun and Weare (2011).

[9] Appendix Table 2 summarizes the entire list of variables employed in the statistical analysis.

The two basic concepts of duration analysis are the survival function and hazard function. The survival function describes the probability of non-adoption until or beyond time t.

$$S(t) = \mathbf{P}(T^* \geq t) = \int_t^\infty f(s)ds \tag{2}$$

In order to avoid assumptions regarding the distribution of survival times, the non-parametric Kaplan-Meier estimator (Kaplan and Meier 1958) and the proportional hazard model by Cox (1972) are the preferred choices. The Kaplan-Meier estimator or product-limit estimator is able to handle right censoring and depicts a stepwise decreasing function of survival times (Wienke 2010). However, the Kaplan-Meier estimator assumes a homogenous population. In contrast, the proportional hazard model does not require that assumption. Furthermore, it allows the inclusion of covariates and enables us to estimate the hazard of adoption for every moment in time. The basic Cox model is described by:

$$h_j(t) = h_0(t)\exp(\beta X_j) \tag{3}$$

where $h_0(t)$ is the baseline hazard function and $X_j$ the covariate vector associated with the vector of regression parameters $\beta$. The baseline hazard function is assumed to be identical for all individuals in the population, and the covariates act multiplicatively on baseline hazard (Wienke 2010).

Nevertheless, the Cox model has a number of drawbacks. First, the assumption that all individuals share the same baseline hazard is questionable as certain (groups of) individuals are more prone to adopt than others. Furthermore, hazards may be neither constant nor proportional over time due to unobserved heterogeneity. Frailty models provide a solution to these issues. These models are proposed by Vaupel et al. (1979) and are extensions of the Cox proportional hazard model (Wienke 2010). They introduce a random effect that acts multiplicatively on the baseline hazard to account for heterogeneity of unobserved covariates. In particular, it becomes possible to address non-independent observations clustered in groups or areas (Rondeau and Gonzalez 2005): "These models [frailty] are recognised as random effect generalisation of standard survival models, in which the random effect term called frailty denotes the unknown, unmeasurable or latent covariates that yield the correlation structure" (Tawiah et al. 2019). We choose a shared frailty model of the following form to fit our data:

$$h_{ij}(t|v_i) = v_i h_0(t)\exp(\beta X_{ij}) \tag{4}$$

where $v_i$ is the random effect associated with the i-th group. The shared frailty model assumes the random effect to be identical within groups but not among groups. Given our data we assume that the frailty parameter, i.e. the random effect, accounts for unobserved heterogeneity embodied in the PAs in which households are located. Hence, our model estimates the hazard of adopting fertiliser based on individual household characteristics as well as the PA-specific measured (PA controls) and unmeasured (PA random effect) variables at any given point in time. Thus, the model assumes an independent and identically distributed frailty parameter from a gamma distribution with mean 1 and unknown variance (Rondeau et al. 2003). In order to jointly estimate the coefficients, the baseline hazard function and the variance of the frailty parameter, a semi-parametric approach with a maximum penalized likelihood estimation based on a robust Marquardt algorithm is applied (Rondeau et al. 2003; Rondeau and Gonzalez 2005; Rondeau et al. 2012).[10] However, the estimation of the baseline hazard function requires an approximation with cubic M-splines to achieve an analytical solution (Rondeau et al. 2012).

### 4.2 Specifications

Because duration analysis originates from medical research, the death of a patient is typically the event of interest, and hence, individuals drop out after the event occurs. Correspondingly, we retain households in the analysis until they adopt fertiliser and drop observations for the adopter in subsequent rounds, i.e. households having adopted before or in 1994 occur only once in the data, whereas we have multiple observations for non-adopters and households having adopted after 1994.

As already mentioned, 679 households adopted before 1994, and we cannot observe their characteristics at the time of adoption. In order to solve the issue of left-truncation and to lose as few observations as possible, we assume time-invariance of culture as our main regressor. Recalling the arguments of Guiso et al. (2006), Tabellini (2008) and Tabellini (2010) and Luttmer and Singhal (2011), we assume time-consistency of religion and ethnicity and use them as proxies for culture. In the same vein, the ethnic and religious composition of households in the PAs is assumed to be static. Ignoring the migration dynamics in the PAs with respect to the fractionalization index appears to be a drawback and source of measurement error, yet we must consider that the ERHS provides only a proportional snapshot and not a comprehensive picture of PA composition.

The paper concerns with first adoption only, that is we do not track dis- and re-adoption behaviours for two reasons. First, the main point of the paper is to elicit the effect of culture on doing something for the first time. Indeed, cultural barriers to adopt diminish after crossing the line for the first time. Secondly, the probability of dis-adoption might largely depends on the performance of the fertilizer, which we do not observe and, in the same vain, the decision to adopt a new technology builds on former experience with that technology.

The passage of time is a main feature of duration models, and we must thus select a suitable starting point. Although, the very first adoption took place in 1958, we do not use this date as a common starting point for our model, as it is not appropriate to assume a link between the usage of fertiliser in southern Ethiopia and the probability of adopting in northern Ethiopia.[11] Instead, we account for distinctions in geographic locations and assign a PA-specific starting point based on the year of the first adoption

[10] An explicit description of maximum penalized likelihood estimation in gamma-frailty models can be found in Rondeau et al. (2003).

[11] The PAs of the ERHS are not close enough to each other to assume spillovers among them. See again Fig. 7 in the Appendix.

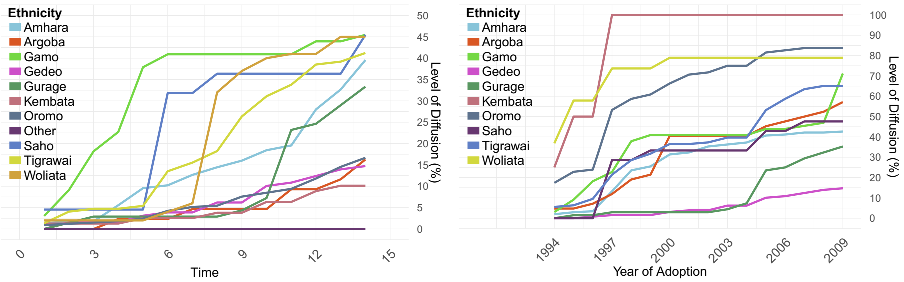


**Fig. 6** Diffusion by Ethnic Groups for two data samples. Source: Author's calculations based on ERHS. The graph on the left-hand side of Fig. 6 presents fertiliser diffusion by ethnic groups for the first 14 years after the launch of fertiliser dissemination in each village. In contrast, the right-hand side graph shows fertiliser diffusion by the same ethnic groups (apart from "Other") between 1994 and 2009 with the exclusion of observations that adopted prior to 1994

in the PA. Using a PA-specific starting point allows us to expect a certain level of awareness on the part of the peasants with regard to the existence of fertiliser and enables us to ensure a degree of observability of fertiliser performance in the PAs.

The left-truncated data prevents us from applying time varying controls, e.g., income or supply constraints, to all observations.[12] We can thus exploit the full dimension of information only with regard to the remaining 771 households, that have not adopted until 1994. In order to not completely exclude the early adopters, we design two subsamples.

The first subset serves to identify the impact of culture during the early diffusion stages in each village, i.e. by taking the PA-specific year of first adoption as starting point for the analysis, we hypothetically set all households to the same starting line. Figure 6 presents the idea for the diffusion curves of ethnic groups. This *early adopter* sample contains 1440 out of 1477 households[13] and is limited to the first 14 years after the launch of fertiliser diffusion. The time constraint stems from the late fertiliser take-up in Adado in 1996 and right-censoring after 2009. Thus we use the *early adopter* sample to analyse adoption behaviour of households whilst they experience the early diffusion stage of their village.

The second subset (*adopters since 1994*) aims to fully exploit time-variant information of households. For this purpose, adopters prior to 1994 are omitted and we analyse adoption behaviour of households facing different diffusion stages depending on their location. The *adopters since 1994* sample covers 771 households over seven survey rounds between 1994 and 2009. To analyse analyse adoption behaviour over time we run the Cox proportional hazard model and the shared frailty model for both samples.

[12] Since we cannot observe household dynamics before 1994, we have to form reliable assumptions in order to minimize bias from unobservable variations, i.e. we control for the migration history of the household heads and adjust the PA-specific starting time to individual entry dates.

[13] 37 households have been excluded from the analysis as they lack information of essential variables.

Finally, our motivation to apply the frailty parameter at the PA level can be found in Rogers (2003) definition of the rate of adoption of innovations, whereby the compatibility of the innovation with the norms and nature of the social system itself affects (aside from other variables) the speed of adoption. In other words, we assume the adoption decision of an individual to be non-independent from the decision of other individuals in the same PA. Moreover, the frailty parameter is able to account for PA-specific values and norms that may not be captured by ethnicity or religion. In addition, external shocks such as the communist revolution in 1974 and the shift towards a federal democratic republic initiated in 1991 are captured, as the effects of a shock change local conditions equally for all peasants within a PA. Thus, if a shock affects PAs differently, the variance of the frailty parameter increases and signals more heterogeneity due to unobservables.

## 5 Results

Our analysis provides evidence for hypothesis *H1*. Culture affects the adoption of fertiliser in Ethiopia. In Table 1[14] the null hypothesis, i.e. the decision to adopt fertiliser is independent from religious or ethnic denominations, returns the following results. Firstly, we can not reject the null hypothesis for religion in any specification, while the decision to adopt depends on ethnicity in all models. Secondly, distinguishing between religious denominations reveals that all religions have a significant higher probability of adopting than *Catholic* for *model 1 (early adopters)*. However the effect is only consistent for *Protestant* followers over all specifications. *Muslim* and *Orthodox Christian* only have higher odds in *model 1 (early adopters)* and *model 3 (early adopters)*, indicating the rather slow appreciation of new ideas by *Catholics*. Thirdly, ethnic groups reveal significant differences in their probability to adopt. Most ethnic groups have lower odds in comparison to the *Amhara* people. Only *Saho* people display reasonable larger probabilities to adopt under the consideration of their socio-economic attributes and their location. The large values might be driven by the worse living conditions which *Saho* people experience with substantially smaller plots and the largest distance to market in comparison to *Amhara*. *Saho* people seem to be particular prone to adopt fertiliser since *Tigrawai* households, that partly share the same conditions as they either live in the same Peasant Association or in the same region, have not significant higher odds to adopt in comparison to *Amhara*. Interestingly, *Kembata* as the only ethnic group with complete fertiliser adoption, has lower odds during the early diffusion stage but catches up at a later point in time. *Gedeo* and *Gurage* households have consistently much lower probabilities to adopt.

Hypothesis *H2* is also verified. Ethnic and religious fractionalization significantly affects the adoption probability. The values indicate that households have lower odds to adopt if the ethnic fractionalization increases, i.e. for households in less

[14] An extended version of Table 1 is available in the Appendix Table 3.

**Table 1** Cox proportional hazard model and the shared frailty model on fertiliser adoption

| Variable | Cox PH | | | | Shared Frailty | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) *early adopters* | | (2) *adopters since 1994* | | (3) *early adopters* | | (4) *adopters since 1994* | |
| | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio |
| **Ethnicity** | 208.43 *** | | 63.468 *** | | 27.335 *** | | 25.533 *** | |
| *Reference: Amhara* | | | | | | | | |
| Argoba | | 0.0489 *** | | 0.3991 | | 0.2543 | | 0.2381 |
| | | (0.5810) | | (0.5965) | | (1.1270) | | (1.6504) |
| Gamo | | 0.0866 *** | | 0.0148 *** | | 0.1663 | | 0.0467 * |
| | | (0.6983) | | (0.8626) | | (1.1382) | | (1.7776) |
| Gedeo | | 0.0013 *** | | 0.0112 *** | | 0.0017 *** | | 0.0001 *** |
| | | (0.7459) | | (0.8778) | | (1.4523) | | (2.9220) |
| Gurage | | 0.0098 *** | | 0.0225 *** | | 0.0149 *** | | 0.0001 *** |
| | | (0.7039) | | (0.8628) | | (1.3039) | | (2.4887) |
| Kembata | | 0.0240 *** | | 1.4960 | | 0.0509 ** | | 8.5100 * |
| | | (0.5089) | | (0.6846) | | (1.3577) | | (1.0937) |
| Oromo | | 0.1166 *** | | 0.6107 | | 0.3304 | | 0.7294 |
| | | (0.3532) | | (0.4655) | | (1.0290) | | (1.5988) |
| Other | | 0.0000 | | | | 0.000 | | |
| | | (21.13) | | | | (15.195) | | |
| Saho | | 10.541 *** | | 4.4537 *** | | 3.0832 | | 163.29 ** |
| | | (0.4628) | | (0.5306) | | (1.1423) | | (2.4351) |
| Tigrawai | | 0.6269 ** | | 0.8089 | | 0.8553 | | 21.985 * |
| | | (0.2019) | | (0.2671) | | (0.5117) | | (1.7678) |
| Woliata | | 0.2574 *** | | 0.8955 | | 0.1852 ** | | 0.2550 |
| | | (0.5143) | | (0.5323) | | (0.7841) | | (1.0508) |

**Table 1** (continued)

| Variable | Cox PH | | | | Shared Frailty | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) *early adopters* | | (2) *adopters since 1994* | | (3) *early adopters* | | (4) *adopters since 1994* | |
| | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio |
| **Religion** | 9.1687 | | 5.4598 | | 7.2333 | | 5.3662 | |
| *Reference: Catholic* | | | | | | | | |
| Muslim | | 2.0668 * | | 0.9656 | | 2.3878 * | | 1.6301 |
| | | (0.4229) | | (0.4291) | | (0.4531) | | (0.4532) |
| None | | 2.8933 ** | | 1.3218 | | 3.0346 | | 2.3864 |
| | | (0.6953) | | (0.6051) | | (0.7166) | | (0.6479) |
| Orthodox Christian | | 2.7554 ** | | 1.1946 | | 2.7543 ** | | 1.6750 |
| | | (0.3951) | | (0.3940) | | (0.4251) | | (0.4324) |
| Other | | 3.2098 ** | | 2.0092 | | 3.0836 * | | 2.7733 * |
| | | (0.5930) | | (0.5774) | | (0.6170) | | 0.6157 |
| Protestant | | 3.7858 *** | | 2.2399 * | | 3.6057 *** | | 2.9463 ** |
| | | (0.4630) | | (0.4676) | | (0.4880) | | (0.4983) |
| **Frac-Eth** | | 0.0032 *** | | 0.0887 *** | | 0.0006 *** | | 0.9812 |
| | | (0.8942) | | (0.7447) | | (1.6808) | | (3.3471) |
| **Frac-Rel** | | 96.484 *** | | 9.5382 ** | | 194.37 *** | | 754.57 ** |
| | | (1.0271) | | (1.0759) | | (1.4598) | | (3.2257) |
| **Household controls** | basic | | complete | | basic | | complete | |
| **PA controls** | basic | | complete | | basic | | complete | |

**Table 1** (continued)

| Variable | Cox PH | | | | Shared Frailty | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) *early adopters* | | (2) *adopters since 1994* | | (3) *early adopters* | | (4) *adopters since 1994* | |
| | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio |
| **Theta** | | | | | 0.5510 ** | | 3.9125 *** | |
| | | | | | (0.3217) | | (1.466) | |
| LCV | 0.4289 | | 0. 3484 | | 0.4224 | | 0.3449 | |
| No. of observations | 3540 | | 3592 | | 3540 | | 3592 | |

Author's calculations based on ERHS. Estimations have been performed using the R frailty package by Rondeau and Gonzalez (2005) and Rondeau et al. (2012). The *early adopters* columns present the result of 1,440 households during the first 14 years after the launch of fertiliser diffusion in each Peasant Association. Since diffusion processes started prior to 1994 in most Peasant Associations, the model controls for fairly time-consistent variables. The *adopters since 1994* columns present the result of 771 households between 1994 and 2009. *Adopters since 1994* omit all 679 households which did adopt prior to 1994 but does control properly for time-variant variables. Significant results for *p<0.1; **p<0.05; ***p<0.01. Standard errors in parentheses. Hazard ratios (H. Ratio) correspond to the exponential of the coefficient. Standard errors refer to the coefficient homogeneous villages, but face higher odds in an environment with diverse religious affiliations. These results hint at the importance of environmental conditions for adoption in the early diffusion stages. The missing significance of *Frac-Eth* in *model 4 (adopters since 1994)* may be driven by the frailty parameter that controls for unobserved heterogeneity at the village level. The results fit the literature as more homophilic systems are superior in terms of spreading new knowledge but require a certain amount of diversity to enable new ideas to enter the local communication channels. We argue that the importance of a low ethnic fractionalization for fertiliser adoption results from the avoidance of potential group frictions and superior conditions of human communication due to a common language and shared values. Thus, increasing ethnic fractionalization fosters interaction barriers and impacts the probability of adoption negatively.

On the contrary, the positive impact of a large variety of religions within rural societies is not intuitive at first glance as the history of humankind has shown repeatedly the devastating impact of religious conflicts. However, except for Debre Berhan, no religious conflicts are reported by the village surveys. The minor occurrence of conflicts may be a result of Ethiopia's historic relations with European and Arabic traders and the presence of Christianity and the Islam since centuries. Yet, the absence of religious conflict in multi-religious societies still does not explain the positive impact on adoption. A potential explanation offers the review of the supplementary village surveys. It is reported that traditional beliefs have been present and partially are still present in rural societies. These naturalistic religions contain the fear of witchcraft, evil eye and other superstitious beliefs. The main drawback of traditional beliefs are the promotion of mistrust, envy and antisocial behaviour (Gershman 2015; 2016). As a solution to these obstacles, Platteau (2009) argues that switching to monotheistic beliefs would help to erase superstition and to support business friendly behaviour. In case of the Ethiopian villages, monotheistic religions formally dominate traditional beliefs. Yet, beliefs are mixed with religions and cherry picking of suitable norms can occur as religious groups do not always comply with their rules (Bevan and Pankhurst 1996a; 1996c). Therefore the positive impact on fertiliser adoption from a religious fragmented society may result from the larger set of available norms that allow to temporarily substitute norms that are inimical for adoption.

Referring to the quantiles for *income*[15] we do neither observe a constant significant influence on adoption nor a constant difference between quantiles in all models. The highest *income* quantile reveals a higher adoption hazard. *Farm size* influences adoption only in one specification and farmers with larger plots do not consistently have higher odds to adopt. Like shown by Dadi et al. (2004) *oxen ownership* increases the odds of adopting as well as receiving *credits*.

Interestingly, households complaining about *high prices* and *supply constraints* show higher probabilities to adopt. A potential explanation might be that adopters complain ex post about high prices, while non-adopters do not perceive the price as

[15]See Appendix Table 3.

too high as they are not aware of them. Complaining about high prices may also stem from disappointment about fertiliser performance and reflects unsatisfied expectations, such that they perceive prices as not justified ex post. These observations can be associated with risk preferences and profitability as seen in Croppenstedt et al. (2003), Dadi et al. (2004) and Dercon and Christiaensen (2011).

Finally, the dominant type of crop cultivated by farmers matters, and the PA-specific diffusion variable reveals its disseminating behaviour, as adoption hazard is lower at the end, when more peasants have already adopted (Griliches 1957; Mansfield 1961).

Comparing the Cox models and the shared frailty extensions with regard to the approximate likelihood cross-validation criterion for the semi parametrical case (LCV), we conclude that the frailty extensions do not offer a substantial improvement in the fit of the models (0.4289 vs. 0.4224 and 0.3484 vs. 0.3449).

Both *adopters since 1994* models reveal a better fit of data due to a broader range of control variables. However, the variance of the frailty parameter is strongly significant in both frailty models suggesting unobserved heterogeneity between the PAs that influences the probability to adopt but is neither captured by standard economic controls nor by our cultural variables.

## 6 Discussion

Thus far, the literature has considered religion as a crucial component of culture to explain economic dissimilarities. Instead, our model suggests that ethnicity plays a stronger role than religion and there are potentially to two reasons for this. First, the data only provides information regarding religious denomination. Therefore, we are unable to verify for the suggested distinction between denomination and active participation in religion. This lack of control may underestimate the effect of religion. A second explanation could be the high level of cultural diversity in Ethiopian society. Religious classification does not seem to be sufficiently specific for capturing the variation in norms and beliefs embedded in ethnicity. Thus, ethnic distinction could be more influential in terms of concealed values, e.g. trust, which may guide the adoption decision (Breuer and McDermott 2012; Gershman 2015).

Another aspect neglected in our analysis thus far is the influence of missionary work. The supplementary village studies report a strong shift from traditional values towards Christian norms in Aze Deboa due to missionary work (Bevan and Pankhurst 1996b). Although adjusting beliefs due to missionary services does not occur immediately, it may weaken norms that initially hinder adoption. Henrich (2000) presents evidence that the understanding of fairness of indigenous people who come into contact with Western society is closer to Western norms than that of indigenous people not exposed to Western norms.

Even though we control for the migration history of households, we cannot observe migration dynamics in the PAs. Migration may play an essential role in terms of the transmission of external knowledge. Apart from norms and beliefs, homophilic

PAs with a low level of migration may share a time-consistent pool of knowledge and lack access to novel information. Migrants with access to an outside pool of knowledge may introduce new habits and broaden the information stock of society. Hence, migrants who already applied the technology in their former PA could introduce the usage of fertiliser, and a follow-up process may be initiated.

Hence, the frailty parameter might capture the influence of missionary work and the influence of unobserved migration dynamics as PA-specific variables and therefore indicates significant unobserved differences between the villages.

Finally, Wienke (2010) highlights limitations of the shared frailty model due to disputable assumptions regarding the shared random effect. In certain circumstances, it is unlikely to always obtain a positive and symmetric correlation between individuals and to be able to assume the same unobserved factors for all members of a group. These issues of identical unobserved components, solely positive associations and symmetric correlation within clusters are important drawbacks of the model.

## 7 Conclusion

The aim of this paper was to analyse the relation between culture and the adoption of innovations as a specific determinant of economic growth. In particular, we investigated cross-cultural dissimilarities with regard to the adoption and diffusion of fertiliser in rural Ethiopia. The application of the Cox proportional hazard model and of its extension, the shared frailty model, indicates a significant effect of culture on the likelihood of adopting fertiliser. Although religion constitutes an important element in the literature, we cannot confirm a relation in our case. Instead, the effect of culture is seen through ethnicity.

The social environment measured by PA-specific fractionalization indices for ethnicity and religion is significant in all models. While diverse religious beliefs within PAs increases the odds to adopt fertiliser, the presence of more than one ethnicity lowers the probability of adoption.

Previously well-examined variables such as income and farm size are not constantly significant. This observation might be driven by the general bad living conditions and the rather marginal differences in welfare. Although we are not able to exploit the complete time dimensional structure of our data due to high left-truncation, the results appear to be robust. This result leads to normative conclusions as well: any policy, such as for instance the use of extension agents, should carefully assess the composition of the village. Whether a policy should prioritize groups more or less receptive to adopt is a political question. Yet, in this paper we can provide guidance about the possible obstacles that such a a policy faces in different contexts. This research is limited to the adoption of fertilizers, but there are no oblivious reasons, why results should not hold for different technologies. We think that further empirical analysis in different contexts and with different adoption choices is a research avenue worth considering.

## Appendix A: Tables

**Table 2** Overview of explanatory and control variables

| Variable | Description | Hypothesis |
|---|---|---|
| Ethnicity | 11 categories (Amhara, Argoba, Gamo, Gedeo, Gurage, Kembata, Oromo, Other, Saho, Tigrawai, Woliata) | H1 |
| Religion | 6 categories (Catholic, Muslim, None, Orthodox Christian, Other, Protestant) | H1 |
| Fra-Eth | Fractionalization Index of ethnicity per PA (continuous variable ranging from 0-1) | H2 |
| Frac-Rel | Fractionalization Index of religion per PA (continuous variable ranging from 0-1) | H2 |
| M.MajorEth | Member of ruling ethnic group in PA (dummy) | Control |
| M.MajorRel | Member of ruling religious group in PA (dummy) | Control |
| Farm Size | Farm Size quantiles (Q1/Q2/Q3/Q4) | Control |
| MainCrop | Main crop cultivated in at farm (barley, coffee, grass, maize, other, sorghum, white teff) | Control |
| AgriItems[a] | Agricultral items quantile (Q1/Q2/Q3/Q4/QNA) | Control |
| Oxen Ownership | Oxen ownership (yes/no/QNA) | Control |
| Lack Labour | Lack of labour force during harvest or seeding (yes/no/QNA) | Control |
| Income[b] | Income quantile (Q1/Q2/Q3/Q4/QNA) | Control |
| Credit | Loan available (yes/no/QNA) | Control |
| Supply Constraints | Problems accessing fertiliser (dummy) | Control |
| High Price | Fertiliser price perceived as too expensive (dummy) | Control |
| Rain Problems | Problems of abundant/insufficient rain (yes/no/QNA) | Control |
| Literacy | Ability to read and / or write (continuous variable ranging from 0-1) | Control |
| Distance km | Distance to next town (market) in kilometres | Control |
| PA.Diff.Lev | Level of fertiliser diffusion in PA (continuous variable ranging from 0-1) | Control |
| PA | PA-specific control which captures unobserved heterogeneity (Adado, Adele Keke, Aze Deboa, Debre Berhan, Dinki, Doma, Gara Godo, Geblen, Haresaw, Imdibir, Koro Degaga, Shumsheha, Sirba na Goditi, Trirufe Ketchema, Yetmen) | Frailty |

[a] AgriItems comprises small agricultural items such as hammer, plough, shovel or spade, hoe, sickle, saddle, chopper or knife as well as more capital-intensive assets such as mills, horses, mules or ox-carts

[b] As a note of caution, the classifications are based on the reported values for the survey round during which households adopted fertiliser or prior to which households were censored, e.g. for uncensored non-adopters income is extracted from the last round in 2009, whereas income from 1999 is used if a household adopted in that year

Source: Variables drawn from the ERHS

**Table 3** Extended results for the Cox proportional hazard model and the shared frailty model on fertiliser adoption

| Variable | Cox PH | | | | Shared Frailty | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) early adopters | | (2) adopters since 1994 | | (3) early adopters | | (4) adopters since 1994 | |
| | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio |
| **Ethnicity** | 208.43 *** | | 63.468 *** | | 27.335 *** | | 25.533 *** | |
| Reference: Amhara Argoba | | 0.0489 *** | | 0.3991 | | 0.2543 | | 0.2381 |
| | | (0.5810) | | (0.5965) | | (1.1270) | | (1.6504) |
| Gamo | | 0.0866 *** | | 0.0148 *** | | 0.1663 | | 0.0467 * |
| | | (0.6983) | | (0.8626) | | (1.1382) | | (1.7776) |
| Gedeo | | 0.0013 *** | | 0.0112 *** | | 0.0017 *** | | 0.0001 *** |
| | | (0.7459) | | (0.8778) | | (1.4523) | | (2.9220) |
| Gurage | | 0.0098 *** | | 0.0225 *** | | 0.0149 *** | | 0.0001 *** |
| | | (0.7039) | | (0.8628) | | (1.3039) | | (2.4887) |
| Kembata | | 0.0240 *** | | 1.4960 | | 0.0509 ** | | 8.5100 * |
| | | (0.5089) | | (0.6846) | | (1.3577) | | (1.0937) |
| Oromo | | 0.1166 *** | | 0.6107 | | 0.3304 | | 0.7294 |
| | | (0.3532) | | (0.4655) | | (1.0290) | | (1.5988) |
| Other | | 0.0000 | | | | 0.000 | | |
| | | (21.13) | | | | (15.195) | | |
| Saho | | 10.541 *** | | 4.4537 *** | | 3.0832 | | 163.29 ** |
| | | (0.4628) | | (0.5306) | | (1.1423) | | (2.4351) |
| Tigrawai | | 0.6269 ** | | 0.8089 | | 0.8553 | | 21.985 * |
| | | (0.2019) | | (0.2671) | | (0.5117) | | (1.7678) |
| Woliata | | 0.2574 *** | | 0.8955 | | 0.1852 ** | | 0.2550 |
| | | (0.5143) | | (0.5323) | | (0.7841) | | (1.0508) |

**Table 3** (continued)

| Variable | Cox PH | | | | Shared Frailty | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) early adopters | | (2) adopters since 1994 | | (3) early adopters | | (4) adopters since 1994 | |
| | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio |
| Religion | 9.1687 | | 5.4598 | | 7.2333 | | 5.3662 | |
| Reference: Catholic | | | | | | | | |
| Muslim | | 2.0668 * | | 0.9656 | | 2.3878 * | | 1.6301 |
| | | (0.4229) | | (0.4291) | | (0.4531) | | (0.4532) |
| None | | 2.8933 ** | | 1.3218 | | 3.0346 | | 2.3864 |
| | | (0.6953) | | (0.6051) | | (0.7166) | | (0.6479) |
| Orthodox Christian | | 2.7554 ** | | 1.1946 | | 2.7543 ** | | 1.6750 |
| | | (0.3951) | | (0.3940) | | (0.4251) | | (0.4324) |
| Other | | 3.2098 ** | | 2.0092 | | 3.0836 * | | 2.7733 * |
| | | (0.5930) | | (0.5774) | | (0.6170) | | 0.6157 |
| Protestant | | 3.7858 *** | | 2.2399 * | | 3.6057 *** | | 2.9463 ** |
| | | (0.4630) | | (0.4676) | | (0.4880) | | (0.4983) |
| Frac-Eth | | 0.0032 *** | | 0.0887 *** | | 0.0006 *** | | 0.9812 |
| | | (0.8942) | | (0.7447) | | (1.6808) | | (3.3471) |
| Frac-Rel | | 96.484 *** | | 9.5382 ** | | 194.37 *** | | 754.57 ** |
| | | (1.0271) | | (1.0759) | | (1.4598) | | (3.2257) |
| M.MajorEth | | 7.0669 *** | | 4.8081 *** | | 1.8260 | | 4.0904 |
| | | (0.3971) | | (0.5763) | | (0.9902) | | (1.5948) |
| M.MajorRel | | 1.1846 | | 0.6688 * | | 1.1854 | | 0.8842 |
| | | (0.1967) | | (0.2243) | | (0.2017) | | (0.2222) |

**Table 3** (continued)

| Variable | Cox PH | | | | Shared Frailty | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) early adopters | | (2) adopters since 1994 | | (3) early adopters | | (4) adopters since 1994 | |
| | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio |
| Farm Size | 5.5513 | | 1.9363 | | 9.2955 ** | | 3.0964 | |
| Reference: Q1 | | | | | | | | |
| Q2 | | 1.3087 * | | 1.1952 | | 1.4209 ** | | 1.1976 |
| | | (0.1487) | | (0.1540) | | (0.1497) | | (0.1557) |
| Q3 | | 1.3186 * | | 1.0046 | | 1.6005 *** | | 0.9224 |
| | | (0.1670) | | (0.1740) | | (0.1666) | | (0.1780) |
| Q4 | | 1.0555 | | 1.0044 | | 1.3026 | | 1.0772 ** |
| | | (0.1749) | | (0.2029) | | (0.1744) | | (0.2144) |
| Main Crop | 26.357 *** | | 11.366 * | | 4.9705 | | 5.3533 | |
| Reference: Barley | | | | | | | | |
| Coffee | | 0.6184 | | 0.5579 | | 0.5794 | | 0.6183 |
| | | (0.47545) | | (0.4494) | | (0.4737) | | (0.47824) |
| Grass | | 0.6392 | | 0.8664 | | 0.8484 | | 0.8848 |
| | | (0.4429) | | (0.4895) | | (0.4511) | | (0.5026) |
| Maize | | 1.6641 * | | 0.7803 | | 1.2933 | | 0.7812 |
| | | (0.2791) | | (0.2601) | | (0.2951) | | (0.2702) |
| Other | | 0.9989 | | 0.76275 | | 1.1830 | | 0.7856 |
| | | (0.2607) | | (0.2322) | | (0.2664) | | (0.2429) |

**Table 3** (continued)

| Variable | Cox PH | | | | Shared Frailty | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) early adopters | | (2) adopters since 1994 | | (3) early adopters | | (4) adopters since 1994 | |
| | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio |
| Sorghum | | 1.2967 | | 0.5545 ** | | 1.1205 | | 0.5615 ** |
| | | (0.2953) | | (0.2660) | | (0.3205) | | (0.2848) |
| White Teff | | 2.1085 *** | | 1.1837 | | 1.2196 | | 0.9009 |
| | | (0.2662) | | (0.2617) | | (0.3024) | | (0.2787) |
| AgriItems | | | 11.274 ** | | | | 37.993 *** | |
| Reference: Q1 | | | | | | | | |
| Q2 | | | | 1.0192 | | | | 1.2139 |
| | | | | (0.1683) | | | | (0.1758) |
| Q3 | | | | 0.7883 | | | | 0.9500 |
| | | | | (0.1839) | | | | (0.1895) |
| Q4 | | | | 0.9701 | | | | 1.0418 |
| | | | | (0.1952) | | | | (0.2024) |
| QNA | | | | 0.5058 *** | | | | 0.2927 *** |
| | | | | (0.2381) | | | | (0.2406) |
| Oxen Ownership | | | 36.963 *** | | | | 32.643 *** | |
| Reference: No | | | | | | | | |
| QNA | | | | 0.2799 | | | | 0.1756 ** |
| | | | | (0.7785) | | | | (0.8479) |
| Yes | | | | 2.1810 *** | | | | 2.0971 *** |
| | | | | (0.1347) | | | | (0.1414) |

**Table 3** (continued)

| Variable | Cox PH | | | | Shared Frailty | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) early adopters | | (2) adopters since 1994 | | (3) early adopters | | (4) adopters since 1994 | |
| | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio |
| Lack of Labour | | | 34.369 *** | | | | 3.8515 | |
| Reference: No | | | | | | | | |
| QNA | | | | 3.8947 *** | | | | 1.2760 |
| | | | | (0.2332) | | | | (0.2255) |
| Yes | | | | 1.2360 | | | | 1.2840 *** |
| | | | | (0.1385) | | | | (0.1404) |
| Income | | | 4.2283 | | | | 7.1915 | |
| Reference: Q1 | | | | | | | | |
| Q2 | | | | 1.1909 | | | | 1.1503 |
| | | | | (0.1666) | | | | (0.1709) |
| Q3 | | | | 1.0849 | | | | 1.0001 |
| | | | | (0.1507) | | | | (0.1550) |
| Q4 | | | | 1.3090 ** | | | | 1.4268 ** |
| | | | | (0.1537) | | | | (0.1573) |
| QNA | | | | 2.1858 | | | | 1.6179 |
| | | | | (0.7863) | | | | (0.8539) |

**Table 3** (continued)

| Variable | Cox PH | | | | Shared Frailty | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) early adopters | | (2) adopters since 1994 | | (3) early adopters | | (4) adopters since 1994 | |
| | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio |
| Credit | | | 4.5918 | | | | 5.9922 * | |
| Reference: No | | | | | | | | |
| QNA | | | | 0.4532 | | | | 0.1958 |
| | | | | (1.0292) | | | | (1.044) |
| Yes | | | | 1.2412 * | | | | 1.2188 * |
| | | | | (0.1106) | | | | (0.1110) |
| Supply Constraints | | | | 5.0315 *** | | | | 4.7690 |
| | | | | (0.2401) | | | | (0.2410) |
| High Price | | | | 5.3050 *** | | | | 5.2969 *** |
| | | | | (0.1594) | | | | (0.1604) |
| Literacy | | | | 1.1610 | | | | 1.2991 *** |
| | | | | (0.1293) | | | | (0.1277) |
| Rain Problems | | | 30.721*** | | | | 4.6814* | |
| Reference: No | | | | | | | | |
| QNA | | | | 0.2409*** | | | | 1.0541 |
| | | | | (0.3155) | | | | (0.2888) |
| Yes | | | | 1.2249 | | | | 1.3402** |
| | | | | (0.1376) | | | | (0.1418) |

**Table 3** (continued)

| Variable | Cox PH | | | | Shared Frailty | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) early adopters | | (2) adopters since 1994 | | (3) early adopters | | (4) adopters since 1994 | |
| | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio | $\chi^2$ | H. Ratio |
| Distancekm | | 0.9304*** | | 0.8678*** | | 1.0394 | | 1.2751 |
| | | (0.0166) | | (0.0317) | | (0.0943) | | (0.1804) |
| PA.Diff.Lev | | 0.0004*** | | 0.7574 | | 0.0001*** | | 0.0027*** |
| | | (0.3986) | | (0.4377) | | (0.4615) | | (0.7444) |
| Theta | | | | | | 0.5510** | | 3.9125*** |
| | | | | | | (0.3217) | | (1.466) |
| LCV | 0.4289 | | 0. 3484 | | 0.4224 | | 0.3449 | |
| No. of observations | 3540 | | 3592 | | 3540 | | 3592 | |

Source: Author's calculations based on ERHS. Estimations have been performed using the R frailty package by Rondeau and Gonzalez (2005) and Rondeau et al. (2012)

The *early adopters* columns present the result of 1,440 households during the first 14 years after the launch of fertiliser diffusion in each Peasant Association. Since diffusion processes started prior to 1994 in most Peasant Associations, the model controls for fairly time-consistent variables. The *adopters since 1994* columns present the result of 771 households between 1994 and 2009. *Adopters since 1994* omit all 679 households which did adopt prior to 1994 but does control properly for time-variant variables

Significant results for *p<0.1; **p<0.05; ***p<0.01. Standard errors in parentheses. Hazard ratios (H. Ratio) correspond to the exponential of the coefficient. Standard errors refer to the coefficient

**Table 4** Cox proportional hazard model with cultural variables

| Variable | *early adopters* | | | | | | | *adopters since 1994* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Reference: Amhara | | | | | | | | | | | | | | |
| Argoba | 0.2954*** | | 0.2850*** | | | | 0.0489*** | 1.2738 | | 1.1196 | | | | 0.3991 |
| Gamo | 2.8397*** | | 2.7676*** | | | | 0.0866*** | 1.8193*** | | 1.4589 | | | | 0.0148*** |
| Gedeo | 0.3312*** | | 0.3062*** | | | | 0.0013*** | 0.2613*** | | 0.2160*** | | | | 0.0112*** |
| Gurage | 1.2291 | | 1.4708 | | | | 0.0098*** | 0.5978** | | 0.6653 | | | | 0.0225*** |
| Kembata | 0.1795*** | | 0.1531*** | | | | 0.0240*** | 15.94*** | | 12.18*** | | | | 1.4960 |
| Oromo | 0.3043*** | | 0.29871*** | | | | 0.1166*** | 3.8989*** | | 3.5022*** | | | | 0.6107 |
| Other | 0.0000 | | 0.0000 | | | | 0.0000 | | | | | | | |
| Saho | 1.3690 | | 1.3452 | | | | 10.541*** | 0.9979 | | 0.9282 | | | | 4.4537*** |
| Tigrawai | 1.3970** | | 1.4012** | | | | 0.6269** | 1.5465*** | | 1.5545*** | | | | 0.8089 |
| Woliata | 1.1508 | | 1.1532 | | | | 0.2574*** | 9.5128*** | | 8.2023*** | | | | 0.8955 |
| Reference: Catholic | | | | | | | | | | | | | | |
| Muslim | | 0.6648 | 1.7145 | | | | 2.0668* | | 3.6094*** | 1.5348 | | | | 0.9656 |
| None | | 2.1689 | 1.4409 | | | | 2.8933** | | 2.4757** | 1.6856 | | | | 1.3218 |
| Orthodox Christian | | 1.5825 | 1.6520 | | | | 2.7554** | | 2.0734** | 1.3411 | | | | 1.1946 |
| Other | | 1.1354 | 1.1673 | | | | 3.2098** | | 2.0519* | 1.6358 | | | | 2.0092 |
| Protestant | | 0.9377 | 1.9878 | | | | 3.7858*** | | 1.6640 | 1.7986 | | | | 2.2399* |
| Frac-Eth | | | | 0.3316*** | | 0.2602*** | 0.0032*** | | | | 1.3508 | | 1.9142* | 0.0887*** |
| Frac-Rel | | | | | 1.0712 | 1.6025** | 96.484*** | | | | | 0.3847*** | 0.3377*** | 9.5382** |

Source: Author's calculations based on ERHS. Estimations have been performed using the R frailty package by Rondeau and Gonzalez (2005) and Rondeau et al. (2012)

The *early adopters* columns present the result of 1,440 households during the first 14 years after the launch of fertiliser diffusion in each Peasant Association. The *adopters since 1994* columns present the result of 771 households between 1994 and 2009. The columns 1 to 6 of both specifications show only cultural effects without considering household or village controls. The results in column 7 of both specifications do control for household or village variables

Significant results for *p<0.1; **p<0.05; ***p<0.01. Standard errors in parentheses. Hazard ratios (H. Ratio) correspond to the exponential of the coefficient. Standard errors refer to the coefficient

**Table 5** Shared frailty model with cultural variables

| Variable | *early adopters* | | | | | | | *adopters since 1994* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Reference: Amhara | | | | | | | | | | | | | | |
| Argoba | 0.4563* | | 0.5352 | | | | 0.2543 | 0.7435 | | 0.8101 | | | | 0.2381 |
| Gamo | 2.0345 | | 1.9135 | | | | 0.1663 | 1.1672 | | 0.7936 | | | | 0.0467* |
| Gedeo | 0.3683* | | 0.3396* | | | | 0.0017*** | 0.1197*** | | 0.0849*** | | | | 0.0001*** |
| Gurage | 1.2403 | | 1.5828 | | | | 0.0149*** | 0.2168** | | 0.2410* | | | | 0.0001*** |
| Kembata | 0.1675*** | | 0.1397*** | | | | 0.0509** | 7.8932*** | | 5.0119** | | | | 8.5100* |
| Oromo | 0.4078*** | | 0.4650** | | | | 0.3304 | 1.4769 | | 1.5480 | | | | 0.7294 |
| Other | 0.0000 | | 0.0000 | | | | 0.0000 | | | | | | | |
| Saho | 2.5226* | | 2.7496* | | | | 3.0832 | 1.0860 | | 1.1246 | | | | 163.29** |
| Tigrawai | 1.5824 | | 1.5804 | | | | 0.8553 | 0.7233 | | 0.6950 | | | | 21.985* |
| Woliata | 0.8470 | | 0.8168 | | | | 0.1852** | 3.1500** | | 2.2860 | | | | 0.2550 |
| Reference: Catholic | | | | | | | | | | | | | | |
| Muslim | | 1.3500 | 1.5452 | | | | 2.3878* | | 1.4639 | 1.3501 | | | | 1.6301 |
| None | | 1.6696 | 1.6428 | | | | 3.0346 | | 2.4510 | 2.1424 | | | | 2.3864 |
| Orthodox Christian | | 2.0154* | 1.8635 | | | | 2.7543** | | 1.6945 | 1.5205 | | | | 1.6750 |
| Other | | 1.2969 | 1.3433 | | | | 3.0836* | | 2.4115* | 2.0339 | | | | 2.7733* |
| Protestant | | 2.1403* | 2.2703* | | | | 3.6057*** | | 2.8922** | 2.3758* | | | | 2.9463** |
| Frac-Eth | | | | 0.2321 | | 0.1124** | 0.0006*** | | | | 0.6210 | | 0.2334 | 0.9812 |
| Frac-Rel | | | | | 1.6087 | 3.0806 | 194.37*** | | | | | 2.2571 | 4.2737 | 754.57** |
| Theta | 0.1874** | 0.5937*** | 0.1945** | 0.5769*** | 0.6260*** | 0.5184*** | 0.5510** | 0.3437** | 1.0656*** | 0.3898** | 1.0570*** | 1.0756*** | 1.0558*** | 3.9125*** |

Source: Author's calculations based on ERHS. Estimations have been performed using the R frailty package by Rondeau and Gonzalez (2005) and Rondeau et al. (2012)

The *early adopters* columns present the result of 1,440 households during the first 14 years after the launch of fertiliser diffusion in each Peasant Association. The *adopters since 1994* columns present the result of 771 households between 1994 and 2009. The columns 1 to 6 of both specifications show only cultural effects without considering household or village controls. The results in column 7 of both specifications do control for household or village variables

Significant results for *p<0.1; **p<0.05; ***p<0.01. Standard errors in parentheses. Hazard ratios (H. Ratio) correspond to the exponential of the coefficient. Standard errors refer to the coefficient

## Appendix B: Figures

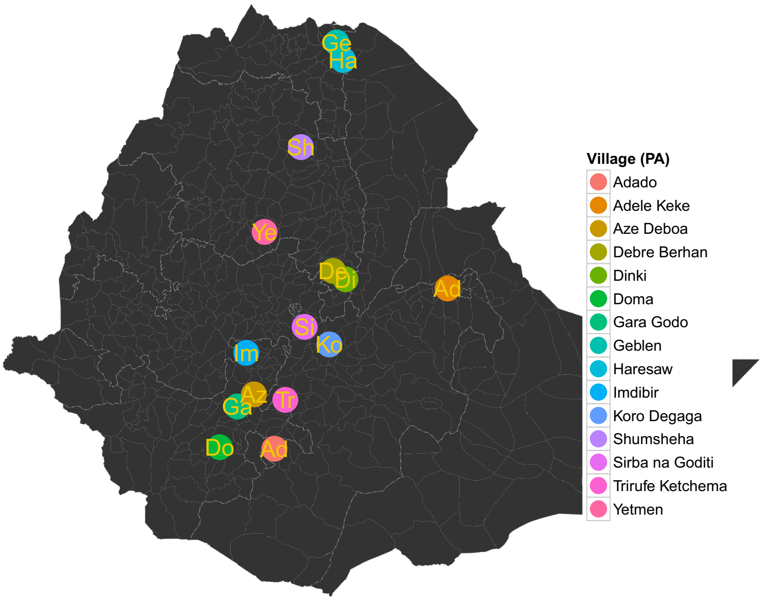


**Fig. 7** Overview about the locations of the ERHS villages. Source: Author's presentation based on supplementary village studies. Overview of the 15 PAs of the ERHS. The PAs are not located in the same woredas (districts)

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