"Cursed is the ground because of you":

Religion, Ethnicity, and the Adoption of Fertilizers 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 fertilizer adoption. We apply a multivariate survival frailty model and find a positive effect on the diffusion of fertilizer. Firstly, social norms, proxied by ethnicity, provide a better explanation for the role of culture, than religion, as usually posited in the literature. Secondly, a homogeneous ethnic environment accelerates the diffusion of fertilizer, while a diverse religious background fosters adoption.

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JEL Classification Codes: O13, O33, Q12, Q16, Z1

1 Introduction

Culture is the foundation of human behaviour. Social norms and beliefs taught during upbringing, 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 centuries, cultures have adjusted to local and economic conditions (Landes, 1998). Nevertheless, our progressively industrializing 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

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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 of economic growth. Moreover, as we use the case of a developing country, we focus on 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 fertilizers 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 fertilizer 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 fertilizer was promoted during the military Derg Regime (1974 - 1991) already and application rates increased by 180 percent between 1993 and 2005 (UNDP, 2010), fertilizer diffusion remains insufficient in rural Ethiopia (Rashid et al., 2013).

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 fertilizer.

In the next sections, we review the literature and suggest testable hypotheses. We then introduce the dataset and present the empirical results. Discussion and conclusion 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 on 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 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 among 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., that preference is determined by the country of birth and persists 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 influences 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 relation 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 positive associated with economic growth, although church attendance has a negative relation when the level of belief is kept constant (Barro and McCleary, 2003). Church attendance thus does not enhance the intensity of belief as a drivers 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 among 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 this paper, 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 or risk preference. 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 relation 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, consideration of the environment's social norms is essential to properly understanding the decision to adopt. 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 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).

On these grounds, we investigate the role of culture in explaining individual adoption behaviour:

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

Although we focus on the individual level, we cannot dismiss the role of the surrounding society, where values and norms are embedded (Magnan et al., 2015). The notion of homophilic and heterophilic systems refers to the extent individuals are similar or different to each other,

[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).

namely sharing the same values and speaking the same language results in a higher degree of homophily and lower degree of heterophily (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.

Another structural dimension of a social system is the obligation to comply with prevailing norms. Obeying norms may hinder the adoption process if norms are inimical to innovation. Additionally, violating norms may result in societal punishment through exclusion from social life. Individuals not belonging to the ruling majority and potentially not completely sharing the prevailing norms may experience a lower cost of rejecting conflicting rules due to their lower level of integration in the rural community (McEachern and Hanson, 2008). We thus test a second hypothesis:

- *H2: The degree of homophily in the social system affects the adoption of chemical fertilizer in rural Ethiopia.*

In the process of hypothesis testing, we account for a number of controls suggested by the literature on adoption. Specifically, Feder et al. (1985) investigate the adoption decision regarding an agricultural innovation in a developing country and find barriers to adoption such as lack of human capital to apply the innovation, lack of labour force related to farm work, as well as credit and supply constraints to purchasing the new technology. 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). Furthermore, farm size (David, 1966), the aggregate level of diffusion (Griliches, 1957) and tenure are pertinent determinants (Feder et al., 1985). To these factors can be added distance to markets and oxen ownership (Sunding and Zilberman, 2001; Dadi et al., 2004).

Finally, prior works fertilizer diffusion in Ethiopia investigate the role of extension agents (Krishnan and Patnam, 2014), education (Asfaw and Admassie, 2004; Weir and Knight, 2004), access to inputs and credits (Croppenstedt et al., 2003; Carlsson et al., 2005) and risk preferences and profitability (Croppenstedt et al., 2003; Dercon and Christiaensen, 2011)[4].

[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.

[4] These works use the same data, i.e., ERHS, but apply partially different rounds. To the best of our knowledge, we are the first exploiting the complete time frame of the ERHS with respect to fertilizer diffusion.

3 Data

3.1 Ethiopia Rural Household Survey

The investigation of culture as a determinant of innovation adoption is conducted by analysing 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 related to agriculture, health and women's activities. We focus on the data collected between 1994 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. 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 the capture of ten ethnic and eight 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 society of Ethiopia[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 fertilizer differs among the PAs. In general, PAs with high soil fertility have less urgency to employ fertilizer. 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 increasing population and scarcity of land. Soil fertility decreases due to on-going deforestation and a lack of fallow land. Additionally, the prices of chemical fertilizer (DAP and Urea) have dramatically increased since 1994 and are thus unaffordable to the majority of farmers. Hence, farmers shift (back) to organic fertilizer such as manure. Aside from high prices, supply shortages and lack of access to loans are important obstacles to acquiring fertilizer. Interestingly, the peasants of two PAs are generally unwilling to adopt chemical fertilizer due to mistrust of its effects or to a reluctance to accept the necessity of stopping soil depletion and erosion.

3.2 Descriptives

By the end of the survey period, 72.51% (1,071 out of 1,477) of the households had adopted fertilizer[8]. The survey is heavily left-truncated as 679 households adopted chemical fertilizer

[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 of six instead of seven rounds, namely 1994, 1995, 1997, 1999, 2004 and 2009.

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

[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.

[8] For our purpose, adoption has taken place once a household has confirmed the usage or the purchase of fertilizer. Nevertheless, we are aware that the application of fertilizer may fluctuate over time and is not necessarily persistent after the first usage (Duflo et al., 2007; Dercon and Christiaensen, 2011; Suri, 2011).

before 1994. By 2009, 406 households had still not adopted fertilizer, of which 120 are right censored due to migration or extinction prior to the last round.

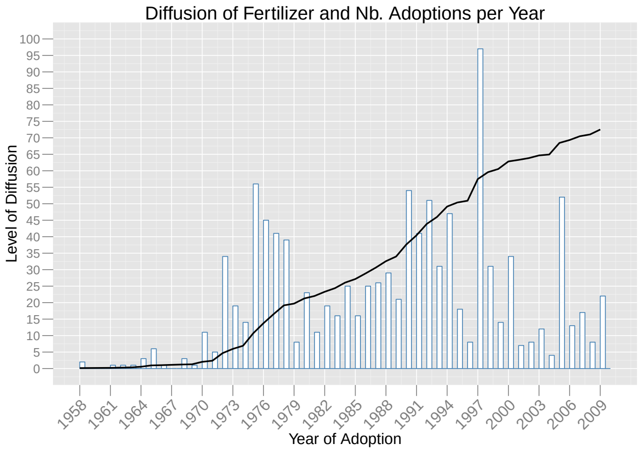

Figure 1: Total fertilizer diffusion and adoptions per year.

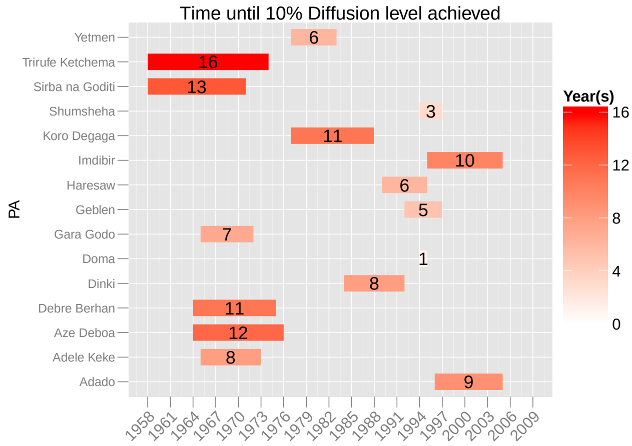

Figure 2: Time to achieve 10% diffusion level per PA.

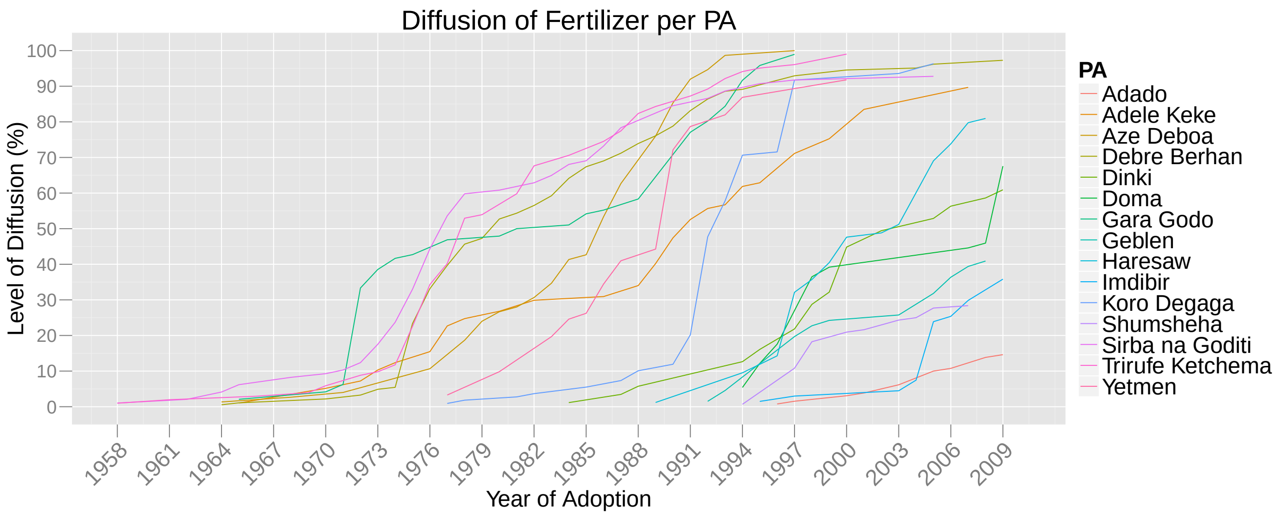

Figure 3: Level of fertilizer diffusion in fifteen PAs between 1958 and 2009.

The total fertilizer diffusion process depicted in Figure 1 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 3 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 Figure 2 and Figure 3 suggests a lack of knowledge or information spillover from country level to PA level, as the amount of time until fertilizer 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 fertilizer has reached a significantly higher level by that time.

Plotting diffusion curves for ethnic and religious groups reveals a similar picture. In line with Weber's theory, Protestants perform more highly 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 adopt.

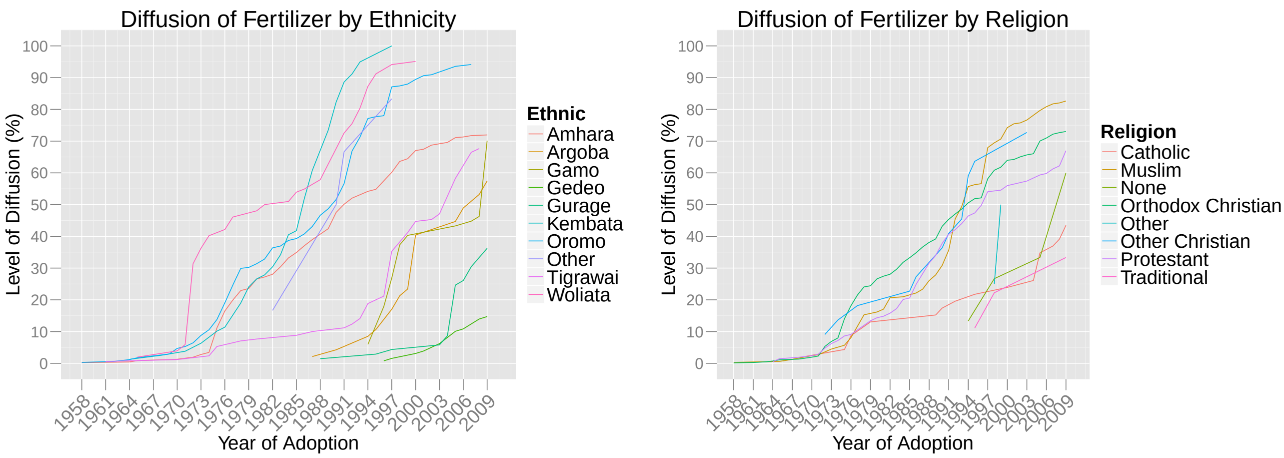

Figure 4: Level of fertilizer diffusion by ethnicity and religion between 1958 and 2009.

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 separately using the Herfindahl-Hirschman Index (HHI) for ethnicity and religion, respectively. The HHI is the sum of the quadratic share of each n different religion (or ethnicity) in a PA. It ranges from $1/n$ to 1 when all the farmers belong to the same religion.

The HHI in Figure 5 shows two perfectly homogenous PAs, namely Yetmen and Shumsheha, with a single religion and a single ethnicity shared by all households. In most cases, the HHI for ethnicity is higher 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 comprised of a single ethnic group.

The right side of Figure 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, Figure 5 shows not only that there is a variability in ethnicity and religious affiliation but also that the two concepts do not overlap very often.

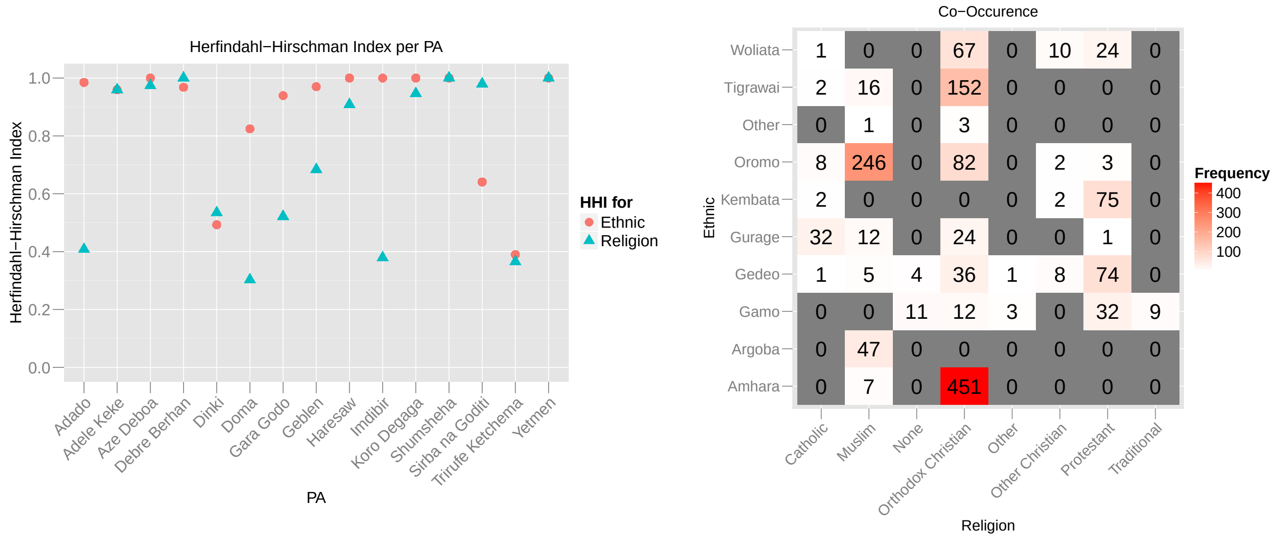

Figure 5: Herfindahl-Hirschman Index for ethnicity and religion per PA and co-occurrence plot of ethnicity and religion.

A closer look at the factors driving the adoption decision (Table 1) validates government policy as 463 households mentioned the efforts of agricultural extension agents as primary reason to adopt. The Ministry of Agriculture organizes programmes to promote and teach the usage of fertilizer using extensions agents who are not necessarily inhabitants of a PA. Rogers (2003) shows the importance of extension agents for the adoption of innovation. However, data show that the importance of the influencer depends to a large extent on his/her similarity with the head of the household.

Adoption	Gender			Ethnic			Age				Wealth			
influenced by	same	different	Tot	same	different	Tot	younger	older	similar	Tot	poorer	richer	similar	Tot
Ext. Agent	0.40	0.07	0.47	0.30	0.17	0.47	0.22	0.11	0.14	0.47	0.01	0.32	0.14	0.47
Network	0.34	0.04	0.38	0.32	0.07	0.38	0.12	0.13	0.13	0.38	0.02	0.24	0.13	0.39
Profitability	0.10	0.01	0.11	0.09	0.02	0.11	0.05	0.02	0.04	0.11	0.01	0.05	0.05	0.11
Other	0.03	0.01	0.04	0.03	0.01	0.04	0.01	0.01	0.01	0.03	0.00	0.02	0.01	0.03
Sum	0.13	0.87	1.00	0.27	0.73	1.00	0.27	0.40	0.33	1.00	0.03	0.64	0.33	1.00

Table 1: Sources of influence on adoption decision.

The variable gender captures the gender correspondence between adopters and influencer. In most of the cases, the two parties involved in the information exchange are male, and this holds both in the case of extension agents and when the exchange involves social ties such as friends, family, and neighbours (network). Because the decision-maker is male in the vast majority of cases, information mainly circulates among males.

In addition, a common ethnic background can facilitate the creation of trust or can lower language barriers because ethnic diversity is associated with diversity of language and habits (Breuer and McDermott, 2012). Thus, we also control for similarity in ethnicity between influencer and adopters, as cultural differences between extension agents or neighbours and potential adopters may hinder diffusion.

Aside from similarity in cultural background, we control 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 may not feel as subject to public pressure to obey them (McEachern and Hanson, 2008). Complementing the Herfindahl Indices, the empirical model accounts for the issue with an ethnic and religious majority measure.

Adoption	Income				Acreage				Agricultural Items			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Yes	93	91	94	102	100	81	88	104	93	93	58	61
No	102	95	94	88	119	65	59	49	70	86	88	98
Sum	195	186	188	190	219	146	147	153	163	179	146	159

Table 2: Quantiles for income, acreage and number of agricultural items.

Finally, we take into account household wealth[9]. Unsurprisingly, the highest numbers of adopters belong to the top income quantile and own more land (Table 2). A more puzzling finding concerns the ownership of agricultural items, which is highest in the lowest quantile of income distribution. This may be due to the broad classification of agricultural items that we use[10], which overestimates the importance of basic agricultural tools, as these are counted as equivalent to more capital-intensive farming equipment. Table 3 summarizes the variables employed in the statistical analysis.

Variable	Description	Hypothesis
Religion	8 categories (Catholic, Muslim, None, Orthodox Christian, Other, Other Christian, Protestant, Traditional)	H1
Ethnicity	10 categories (Amhara, Argoba, Gamo, Gedeo, Gurage, Kembata, Oromo, Other, Tigrawai, Woliata)	H1
HHI-REL	Herfindahl Index of religion per PA (continuous variable ranging from 0-1)	H2
HHI-ETH	Herfindahl Index of ethnicity per PA (continuous variable ranging from 0-1)	H2
QIncome	Income quantile (Q1/Q2/Q3/Q4/QNA)	Control
QAgriItems	Agricultral items quantile (Q1/Q2/Q3/Q4/QNA)	Control
QAcreage	Acreage quantile (Q1/Q2/Q3/Q4/QNA)	Control
Oxen Owned	Oxen ownership (yes/no/QNA)	Control
Lack Oxen	Lack of oxen during harvest or seeding (yes/no/QNA)	Control
Lack Labour	Lack of labour force during harvest or seeding (yes/no/QNA)	Control
Shortcoming Fertilizer	Problems with access to fertilizer (high price/no problem/supply shortage/QNA)	Control
Loan100Birr	Loan available (yes/no/QNA)	Control
Rain Problems	Problems overabundant/insufficient rain (yes/no/QNA)	Control
Read	Literacy (yes/no/QNA)	Control
Write	Literacy (yes/no/QNA)	Control

[9] As a note of caution, in Table 2 the classifications within the variables are based on the reported values for the survey round during which households adopted fertilizer 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. Households that adopted before 1994 are not represented in Table 2 due to left-truncation of the observations.

[10] The term "agricultural items" comprises small 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.

Variable	Description	Hypothesis
M.MajorEth	Member of ruling ethnic group in PA (yes/no/QNA)	Control
M.MajorRel	Member of ruling religious group in PA (yes/no/QNA)	Control
Reason to adopt	Driver of fertilizer adoption (extension agent/ friends, neighbours and relatives/ observed profitability/ other/ QNA)	Control
Teacher-Fertilizer-Skills	Actor teaching usage of fertilizer (extension agent/ friends, neighbours and relatives/ observing others/ other/ QNA)	Control
Gender	Sex of influencing actor (same/other/QNA)	Control
Age	Age of influencing actor (older/younger/equal/QNA)	Control
Ethnic	Ethnicity of influencing actor (same/different/QNA)	Control
Wealth	Wealth of influencing actor (richer/poorer/equal/QNA)	Control
Distancekm	Distance to next town (market) in kilometres	Control
PA.Diff.Lev	Level of fertilizer diffusion in PA (continuous variable ranging from 0-1)	Control
MainCrop	Main crop cultivated in PA (barley, cereals, coffee, enset, millet, teff, wheat)	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

Table 3: Overview of explanatory and control variables that are applied to investigate their effect on the adoption of fertilizer.

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 fertilizer 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, 1987); Karshenas and Stoneman (1993); Carletto et al. (1999); Baptista (2000); Carter et al. (2001); Burton et al. (2003); Dadi et al. (2004) and Jun and Weare (2011).

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.

$$S(t) = \mathbf{P}(T^* \geq t) = \int_t^\infty f(s)ds \tag{1}$$

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:

$$h_j(t) = h_0(t) \exp(\beta X_j) \tag{2}$$

where $h_0(t)$ is the baseline hazard function, X_j the covariate vector associated with the vector of regression parameters β. 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). We choose a shared frailty model of the following form to fit our data:

$$h_{ij}(t|v_i) = v_i h_0(t) \exp(\beta X_{ij}) \tag{3}$$

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 fertilizer 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)[11]. 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 fertilizer 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.

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

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 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, 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 HHIs 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 passage of time is a main feature of duration models, and we must thus select a suitable starting point. Although, the 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 fertilizer in southern Ethiopia and the probability of adopting in northern Ethiopia[12]. Instead, we account for distinctions in geographic locations and assign a PA-specific starting point based on the year of the first adoption 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 fertilizer and enables us to ensure a degree of observability of fertilizer performance in the PAs.

The left-truncated data prevents us from applying time varying controls, e.g., income or acreage, to all observations[13]. We can thus exploit the full dimension of information only with regard to the remaining 798 households. In order to not completely exclude the early adopters, we run the Cox and the shared frailty model with PA-specific starting times for the complete time period (1958-2009) with all households and for a reduced data set (1994-2009) that excludes the left-truncated observations.

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 to a federal democratic republic initiated in 1991 are captured, as the peasants of a PA experience the effects of the shocks though a change in conditions equally within but not automatically among PAs. Thus, if a shock affects PAs differently, the variance of the frailty parameter increases and signals more heterogeneity due to unobservables.

[12] The PAs of the ERHS are not close enough to each other to assume spillovers among them. See again Figure 6 in the Appendix.

[13] 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.

5 Results

Our analysis provides evidence for hypothesis *H1*. Culture affects the adoption of fertilizer in Ethiopia. In Table 4[14] the null hypothesis, i.e., the decision to adopt fertilizer is independent from religious or ethnic denominations, returns the following results. Firstly, we can reject the null for religion only in *model 1 (Cox 1958:2009)*, while the decision to adopt depends on ethnicity in three of the four models. Secondly, distinguishing between religious denominations, *Catholic* shows a significant lower probability of adopting than *Muslim*, *Orthodox Christian* and *Protestant* as well as than atheists (*None*) and the melting pot of *Other* religions in *model 1 (Cox 1958:2009)*. Thirdly, ethnic groups reveal certain significant differences in terms of the probability of adopting. Thus, *Kembata* people have a lower adoption hazard in *model 2 (Cox 1994:2009)* and *model 4 (Shared Frailty 1994:2009)* given that 75 of 79 *Kembata* households adopted before 1994 and the remaining four households adopted by 1997. Hence, no *Kembata* are at risk in the last three rounds.

Hypothesis *H2* is partially verified. Considering all adopters (*model 1* and *model 3*), the households' environment significantly affects the adoption of fertilizer. Thus, living in PAs with low religious diversity seems to hinder the adoption decision. In contrast, lower ethnic diversity facilitates adoption. Neither result remains significant in the reduce *models (2, 4)*. These results may hint at the importance of environmental conditions for adoption in the early stages diffusion and coincides with hypothesis *H2*. 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 a larger number of religious denominations represents higher exposure to new information due to a broader pool of external information channels, e.g., knowledge exchange during pilgrimages. However, a higher level of homogeneity ensures fewer frictions among individuals thanks to common values and language. In short, religion may determine the source of information, but to transmit these ideas a similar background in terms of language and non-religious values and norms is required which may be represented by ethnicity.

Referring to the quantiles for *income*, *agricultural items* and *acreage*, we observe a significant influence on adoption in all models. The *income* group *QNA*, i.e., households who did not state their income and early adopters (before 1994), reveal a higher adoption hazard. Two factors may drive this result. Firstly, as we do not have information regarding income for all early adopters, 63.39% of total adoptions are associated with the *QNA* income class. Secondly, the consistently higher degree of probability (even in *model 2* and *4*) could result from a relatively high income not being reported by the interviewee due to fear of additional tax payments. With respect to *agricultural items*, the significance of *Q2* suggests the need for a certain stock of farming equipment in order to achieve circumstances suitable to the appropriate application of fertilizer. Finally, in line with Feder et al. (1985) or David (1966), *farm size* is relevant to the adoption decision, and we observe a significantly higher probability of adopting for households

[14] An extended version of Table 4 is available in the Appendix Table 5.

with larger acreages (*Q4* vs. *Q1*).

Lacking *labour force* and lacking *oxen power* during harvest or seeding appear to have a slight and no impact on fertilizer adoption, respectively. In contrast, *oxen ownership*, as suggested by Dadi et al. (2004), increases the odds of adopting. The contrasting observations for both oxen variables may not be related to the use of oxen in a farmer’s field directly but instead to the possibility that oxen owners may lend an animal in exchange for cash or other equivalents, which may enlarge their financial scope of action compared with households that must borrow oxen. Hence, households without oxen may not face a lack as they can borrow an animal, however, this also limits their financial options.

		Cox				Shared Frailty			
		(1) 1958-2009		(2) 1994-2009		(3) 1958-2009		(4) 1994-2009	
		χ^2	H. Ratio	χ^2	H. Ratio	χ^2	H. Ratio	χ^2	H. Ratio
	Religion	21.17***		4.14		7.42		4.22	
	Reference: Catholic								
	Muslim		2.69***		1.25		1.64*		1.25
			(0.3292)		(0.4615)		(0.2911)		(0.4596)
	None		3.69**		1.83		1.79		1.83
			(0.5347)		(0.6491)		(0.5117)		(0.6431)
	Orthodox Christian		3.56***		1.51		1.75**		1.51
			(0.3194)		(0.4309)		(0.2826)		(0.425)
	Other		4.44*		2.24		2.76		2.24
			(0.827)		(0.9122)		(0.8091)		0.9034
	Other Christian		1.94		3.4		1.14		3.40**
			(0.4356)		(0.7505)		(0.3967)		0.7416
	Protestant		3.9***		2.25		2.02**		2.25
			(0.3609)		(0.5021)		(0.3264)		(0.4972)
	Traditional		3.22		1.81		1.51		1.81
			(0.7129)		(0.8087)		0.6949		(0.7997)
	Ethnicity	55.08***		37.85***		2.9		37.63***	
H1	*Reference: Amhara*								
	Argoba		6.83***		0.99		1.22		0.99
			(0.3843)		(1.3107)		(0.4196)		(1.4372)
	Gamo		6.43**		0.18		0.68		0.18
			(0.7866)		(1.3144)		(0.8772)		(1.3803)
	Gedeo		3258		1084		2679		4245
			(14.902)		(14.92)		(15.29)		(23.04)
	Gurage		4.4*		0.64		0.52		0.64
			(0.8138)		(1.1263)		(1.8862)		(1.1521)
	Kembata		1.57		0.01***		1.51		0.008***
			(0.6904)		(1.1618)		(0.6358)		(1.1929)
	Oromo		1.67***		0.27		1.17		0.27
			(0.1899)		(1.0839)		(0.2769)		(1.1672)
	Other		2.2		33.18***		0.91		33.18***
			(0.585)		(1.3115)		(0.6837)		(1.3607)
	Tigrawai		1.55**		0.99		0.93		0.99
			(0.1762)		(0.5682)		(0.2959)		(0.5908)
	Woliata		4.13***		0.17		1.48		0.17
			(0.3171)		(1.2574)		(0.4306)		(1.2421)
	HHI-REL		0.03***		0.34		0.001***		0.34
			(0.7242)		(1.1568)		(2.4356)		(1.1436)
H2	**HHI-ETH**		65.72***		0.14		27886***		0.14
			(0.5558)		(1.593)		(2.1225)		(1.8069)

		Cox				Shared Frailty			
		(1) 1958-2009		(2) 1994-2009		(3) 1958-2009		(4) 1994-2009	
		χ^2	H. Ratio	χ^2	H. Ratio	χ^2	H. Ratio	χ^2	H. Ratio
Control: Household Characteristics	**Income-Quantiles**	11.31 **		14.73 ***		10.04 **		14.75 ***	
	AgriItems-Quantiles	18.59 ***		11.09 **		34.55 ***		11.1 **	
	Acreage-Quantiles	30.74 ***		11.4 **		15.26 ***		11.23 **	
	Oxen Ownership	4.12		6.51 **		5.29 *		6.54 **	
	Lack of Oxen	2.40		3.84		3.57		3.84	
	Lack of Labour	3.20		4.6 *		2.24		4.59 *	
	Limitations	213.04 ***		193.42 ***		213.74 ***		193.05 ***	
	Loan100Birr	6.39 **		3.11		8.57 **		3.12	
	Rain Problems	30.91 ***		17.22 ***		26.82 ***		17.15 ***	
	Read		1.29		1.03		1.07		1.03
	Reference: No		(0.1663)		(0.3139)		(0.1628)		(0.3138)
	Write		0.92		1.08		1.02		1.08
	Reference: No		(0.1674)		(0.3171)		(0.1636)		(0.3171)
	M.MajorEth		0.69 *		1.24		0.79		1.24
	Reference: No		(0.1988)		(1.1994)		(0.2723)		(1.2976)
	M.MajorRel		0.95		0.84		0.96		0.84
	Reference: No		(0.1389)		(0.2211)		(0.1376)		(0.2216)
Control: Influence	**Reason to adopt**	39.65 ***		44.34 ***		30.4 ***		44.36 ***	
	Gender	1.47		2.16		1.32		2.14	
	Age	2.51		17.8 ***		1.72		17.82 ***	
	Ethnic	12.78 ***		5.81 *		7.21 **		5.82 *	
	Wealth	14.15 ***		9.10 **		5.62		5.49	
	Teacher-Fertilizer-Skills	6.11		4.62		5.71		4.62	
Control: PA	**Distancekm**		1.08 ***		0.99		1.1		0.99
			(0.0179)		(0.0645)		0.0682		(0.0685)
	PA.Diff.Lev		0.01 ***		0.19 **		0.002		0.19 **
			(0.214)		(0.66)		(0.2284)		(0.6572)
	MainCrop	140.14 ***		49.8 ***		33.54 ***		44.85 ***	
Frailty	Theta						0.66 **		6.9e-17
							(0.2997)		(1.03e-09)
	LCV	0.7118		0.3151		0.6957		0.3154	
	No. observation	4369		3692		4369		3692	

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4: Cox proportional hazard model and shared frailty model on adoption of fertilizer for two time periods each. All estimations have been performed using the R frailty package by Rondeau and Gonzalez (2005) and Rondeau et al. (2012) on the basis of the ERHS.

Interestingly, households reporting not having problems with access to fertilizer display a lower probability of adopting than those complaining of excessively high prices. There could be thus a distinction between knowing the distribution channels, having access to them but not purchasing fertilizer, and the real action of adoption in spite of high prices. In other words, adopters complain ex post regarding high prices, while non-adopters know ex ante how to access fertilizer but do not perceive the price as too high. Potentially, both answers contain both dissatisfaction and aspirations. Non-adopters do not mention problems as they have no interest in adopting, or they do not regard prices as inappropriate because they presume that fertilized fields outperform normal harvests. These expectations result in disappointment after adoption if fertilizer does not boost yields, such that they perceive prices as not justified ex post. These observations can be associated to risk preferences and profitability as seen in Croppenstedt et al. (2003), Dadi et al. (2004) and Dercon and Christiaensen (2011).

Similarly to income, the significance of *QNA* for financial loans may be due to the left-truncation of most adopters in combination with the unwillingness to report detailed financial information. Finally, households facing problems with rain are more likely to adopt fertilizer, potentially in the hope of rescuing the harvest.

In contrast to Asfaw and Admassie (2004) and Weir and Knight (2004) neither the ability to read nor to write is pertinent. In contradiction to our assumption, public pressure to obey norms does not seem not to hinder adoption significantly, as membership in a major ethnicity or religion is only weakly significant in one specification.

With respect to influence on adoption, we have to adjust our understanding of *QNA*. *QNA* currently comprises households that have not answered mainly because they have not adopted, and contrary to the time-variant variables above, early adopters are not captured in *QNA* as they are able to answer retrospectively. Apart from the summation of class *Other*, we do not observe significant differences among the sources of fertilizer adoption. However, *QNA* correctly depicts a significantly lower probability of adopting.

Among the characteristics of the influential person, gender is not significant. Sharing a similar age and ethnicity increases the hazard of adopting, while the significance of wealth disappears with the introduction of the frailty parameter.

Finally, the dominant type of crop cultivated in the PA 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 (0.7118 vs. 0.6957 and 0.3151 vs. 0.3154).

Both short models reveal a better fit of data due to fewer missing values. However, the variance of the frailty parameter is only significant in *model 3*, suggesting less unobserved heterogeneity between the PAs for *model 4*. The reason why *theta* is significant in *model 3* may be due to missing values for the time-variant variables of the left-truncated observations in combination with different starting points of the diffusion process.

6 Discussion

Thus far, the literature has considered religion as a crucial component of culture to explain economic dissimilarities. Instead, our model suggests ethnicity plays a stronger role than religion due potentially to two reasons. First, the data only provides information regarding religious denomination. Therefore, we are unable to control 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 seems to be not sufficiently specific to capture 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 narrative PA studies report a strong shift from traditional values towards Christian norms in Aze Deboa due to missionary work. 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 have had contact with Western society is closure to Western norms than that of indigenous people not exposed to Western norms.

Although 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 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 fertilizer, and a follow-up process may be initiated.

Nonetheless, our frailty parameter would capture the influence of missionary work and the influence of unobserved migration dynamics as PA-specific variables. Recalling our results, the observed variance of the frailty parameter does not suggest significant unobserved heterogeneity among the PAs.

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.

With respect to our model, we claim to have a symmetrical correlation structure and identical unobserved variables within groups. We justify our claim by the low variance of the frailty parameter in our model, and therefore we assume we are controlling for the main elements of unobserved heterogeneity. Thus, we attribute the persisting unobserved component to PA-specific norms and beliefs that religious or ethnic denominations do not capture. Nevertheless, we cannot deny the issue of strictly positive associations. Depending on the content of the non-visible norms, we may face negative associations between individuals of the same cluster due to the hindering character of those norms.

7 Conclusion

The aim of the paper was to analyse the relation between culture and the adoption of innovations as a specific determinant of economic growth. In particular, we investigate cross-cultural dissimilarities with regard to the adoption and diffusion of fertilizer 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 fertilizer. Although religion constitutes an important element in the literature, we cannot confirm a relation in our case. Instead, the effect of culture works via ethnicity.

The social environment measured by PA-specific Herfindahl-Hirschman Indices for ethnicity and religion is significant in the early adoption models. While religious beliefs within PAs should be diverse, a uniform ethnicity among peasants appears to be conducive to the adoption of fertilizer.

Previously well-examined variables such as income, acreage or diffusion level are significant, as expected. 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.

Further investigations require a deeper analysis of PA- and ethnicity-specific norms that may promote or delay initial adoption decisions.

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Appendix

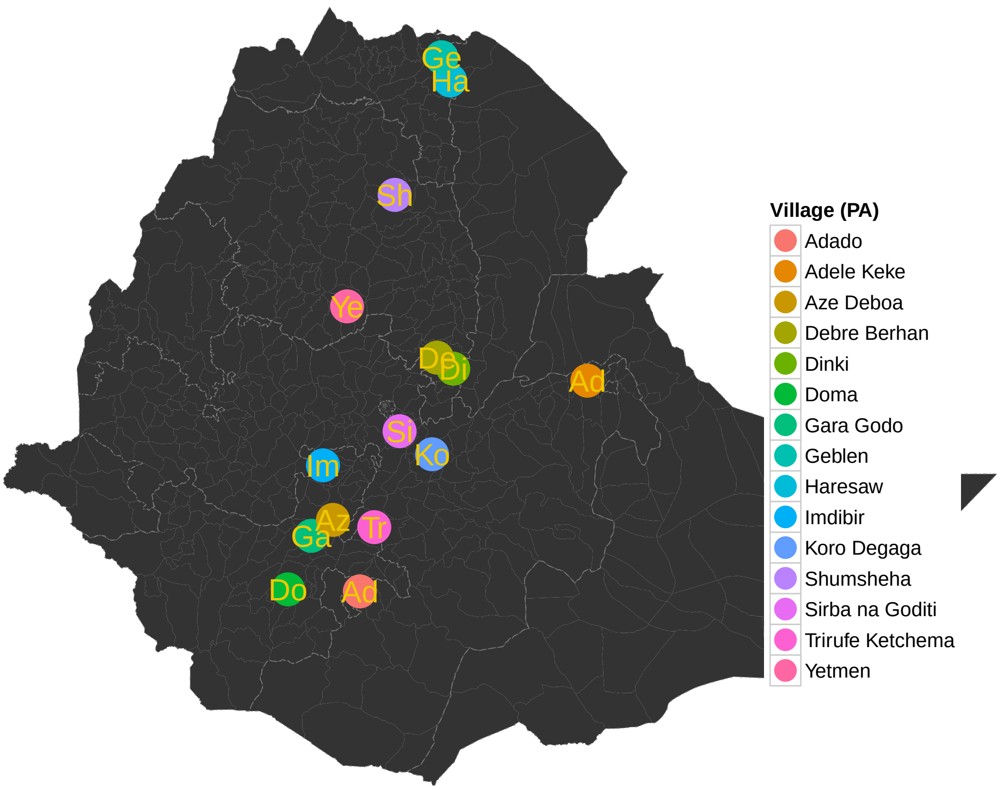

Figure 6: Overview of the 15 PAs of the ERHS. The PAs are not located in the same woredas (districts).

		Cox				Shared Frailty				
		(1) 1958-2009		(2) 1994-2009		(3) 1958-2009		(4) 1994-2009		df
		χ^2	H. Ratio	χ^2	H. Ratio	χ^2	H. Ratio	χ^2	H. Ratio	
H1	**Religion**	21.17 ***		4.14		7.42		4.22		7
	Reference: Catholic									
	Muslim		2.69 ***		1.25		1.64 *		1.25	
			(0.3292)		(0.4615)		(0.2911)		(0.4596)	
	None		3.69 **		1.83		1.79		1.83	
			(0.5347)		(0.6491)		(0.5117)		(0.6431)	
	Orthodox Christian		3.56 ***		1.51		1.75 **		1.51	
			(0.3194)		(0.4309)		(0.2826)		(0.425)	
	Other		4.44 *		2.24		2.76		2.24	
			(0.827)		(0.9122)		(0.8091)		0.9034	
	Other Christian		1.94		3.4		1.14		3.40 **	
			(0.4356)		(0.7505)		(0.3967)		0.7416	
	Protestant		3.9 ***		2.25		2.02 **		2.25	
			(0.3609)		(0.5021)		(0.3264)		(0.4972)	
	Traditional		3.22		1.81		1.51		1.81	
			(0.7129)		(0.8087)		0.6949		(0.7997)	
	Ethnicity	55.08 ***		37.85 ***		2.9		37.63 ***		9
	Reference: Amhara									
	Argoba		6.83 ***		0.99		1.22		0.99	
			(0.3843)		(1.3107)		(0.4196)		(1.4372)	
	Gamo		6.43 **		0.18		0.68		0.18	
			(0.7866)		(1.3144)		(0.8772)		(1.3803)	
	Gedeo		3258		1084		2679		4245	
			(14.902)		(14.92)		(15.29)		(23.04)	
	Gurage		4.4 *		0.64		0.52		0.64	
			(0.8138)		(1.1263)		(1.8862)		(1.1521)	
	Kembata		1.57		0.01 ***		1.51		0.008 ***	
			(0.6904)		(1.1618)		(0.6358)		(1.1929)	
	Oromo		1.67 ***		0.27		1.17		0.27	
			(0.1899)		(1.0839)		(0.2769)		(1.1672)	
	Other		2.2		33.18 ***		0.91		33.18 ***	
			(0.585)		(1.3115)		(0.6837)		(1.3607)	
	Tigrawai		1.55 **		0.99		0.93		0.99	
			(0.1762)		(0.5682)		(0.2959)		(0.5908)	
	Woliata		4.13 ***		0.17		1.48		0.17	
			(0.3171)		(1.2574)		(0.4306)		(1.2421)	
H2	**HHI-REL**		0.03 ***		0.34		0.001 ***		0.34	
			(0.7242)		(1.1568)		(2.4356)		(1.1436)	
	HHI-ETH		65.72 ***		0.14		27886 ***		0.14	
			(0.5558)		(1.593)		(2.1225)		(1.8069)	
Control: Household Characteristics	**Income-Quantiles**	11.31 **		14.73 ***		10.04 **		14.75 ***		4
	Reference: Q1									
	Q2		1.22		1.13		1.13		1.13	
			(0.1695)		(0.1703)		(0.1663)		(0.1704)	
	Q3		0.96		0.99		0.95		0.99	
			(0.1561)		(0.1602)		(0.1528)		(0.1602)	
	Q4		1.05		1.16		1.1		1.16	
			(0.1622)		(0.1639)		(0.1623)		(0.1639)	
	QNA		4.67 ***		6.55 ***		4.59 ***		6.55 ***	
			(0.5085)		(0.5099)		(0.5221)		(0.5097)	
	AgriItems-Quantiles	18.59 ***		11.09 **		34.55 ***		11.1 **		4
	Reference: Q1									
	Q2		1.49 **		1.33		1.65 ***		1.33	
			(0.1717)		(0.1848)		(0.1719)		(0.1845)	

Control: Household Characteristics

Q3		1.13		0.91		1.28		0.91	
		(0.1848)		(0.1942)		(0.1843)		(0.194)	
Q4		1.04		1.11		1.26		1.12	
		(0.2033)		(0.2061)		(0.2019)		(0.206)	
QNA		0.59 **		0.61 **		0.45 ***		0.61 **	
		(0.211)		(0.2461)		(0.216)		(0.2459)	
Acreage-Quantiles	30.74 ***		11.4 **		15.26 ***		11.23 **		4
Reference: Q1									
Q2		1.9 ***		1.35		1.23		1.35	
		(0.1891)		(0.1935)		(0.1864)		(0.1941)	
Q3		1.98 ***		1.36		1.36		1.36	
		(0.2008)		(0.2035)		(0.197)		(0.2036)	
Q4		2.77 ***		1.62 **		1.81 ***		1.62 **	
		(0.2123)		(0.2207)		(0.2122)		(0.2211)	
QNA		0.78		0.6		0.61 *		0.6	
		(0.2873)		(0.3128)		(0.2806)		(0.3129)	
Oxen Ownership	4.12		6.51 **		5.29 *		6.54 **		2
Reference: No									
Yes		1.23		1.34 **		1.29 **		1.34 **	
		(0.1329)		(0.1446)		(0.131)		(0.1445)	
QNA		0.59		0.54		0.61		0.54	
		(0.4936)		(0.4883)		(0.5075)		(0.4874)	
Lack of Oxen	2.40		3.84		3.57		3.84		2
Reference: No									
Yes		0.90		0.82		0.77		0.82	
		(0.1555)		(0.162)		(0.1577)		(0.1622)	
QNA		2.43		2.71		2.13		2.71	
		(0.639)		(0.6428)		(0.8226)		(0.6432)	
Lack of Labour	3.20		4.6 *		2.24		4.59 *		2
Reference: No									
Yes		1.15		1.01		1.15		1.01	
		(0.1497)		(0.1538)		(0.1469)		(0.1538)	
QNA		2.68		4 **		2.6		4 **	
		(0.642)		(0.647)		(0.8247)		(0.6475)	
Limitations	213.04 ***		193.42 ***		213.74 ***		193.05 ***		4
Reference: High Price									
No problem		0.19 ***		0.22 ***		0.18 ***		0.22 ***	
		(0.237)		(0.2401)		(0.236)		(0.2402)	
Other		0.65 *		0.65 *		0.69		0.65 *	
		(0.2395)		(0.2489)		(0.2391)		(0.2491)	
QNA		0.08 ***		0.06 ***		0.07 ***		0.06 ***	
		(0.1847)		(0.2181)		(0.1971)		(0.2184)	
Shortage of Supply		1.09		1.12		1.07		1.12	
		(0.2141)		(0.2181)		0.2109		(0.2182)	
Loan100Birr	6.39 **		3.11		8.57 **		3.12		2
Reference: No									
Yes		1.24 *		1.12		1.18		1.12	
		(0.1143)		(0.115)		(0.1121)		(0.115)	
QNA		2.23 **		0.18		2.81 ***		0.18	
		(0.4073)		(1.2058)		(0.379)		(1.2014)	
Rain Problems	30.91 ***		17.22 ***		26.82 ***		17.15 ***		2
Reference: No									
Yes		1.41 **		1.09		1.39 **		1.09	
		(0.1409)		(0.141)		(0.1363)		(0.1411)	
QNA		0.36 ***		0.24 ***		0.41 ***		0.24 ***	
		(0.2893)		(0.3902)		(0.2856)		(0.3918)	
Read		1.29		1.03		1.07		1.03	
Reference: No		(0.1663)		(0.3139)		(0.1628)		(0.3138)	
Write		0.92		1.08		1.02		1.08	
Reference: No		(0.1674)		(0.3171)		(0.1636)		(0.3171)	
M.MajorEth		0.69 *		1.24		0.79		1.24	

	Reference: No		(0.1988)		(1.1994)		(0.2723)		(1.2976)	
	M.MajorRel		0.95		0.84		0.96		0.84	
	Reference: No		(0.1389)		(0.2211)		(0.1376)		(0.2216)	
Control: Attributes of influential person	**Reason to adopt**	39.65 ***		44.34 ***		30.4 ***		44.36 ***		4
	Reference: ExtAgents									
	Friends/Neighb./Relat.		0.91		0.69		0.92		0.69	
			(0.0996)		(0.2992)		(0.0995)		(0.2997)	
	Noticed Profitability		1.03		0.88		0.93		0.88	
			(0.1503)		(0.4827)		(0.1477)		(0.4853)	
	Other		1.23		36.4 **		1.08		36.4 **	
			(0.2142)		(1.4989)		(0.2151)		(1.5072)	
	QNA		0.06 ***		0.05 ***		0.08 ***		0.05 ***	
			(0.451)		(0.4918)		(0.4565)		(0.4924)	
	Gender	1.47		2.16		1.32		2.14		2
	Reference: Different									
	Same		1.16		2.25		1.01		2.25	
			(0.1403)		(0.6337)		(0.1351)		(0.6349)	
	QNA		1.8		3.89		2.09		3.89	
			(0.7444)		(1.2102)		(0.6462)		(1.2152)	
	Age	2.51		17.8 ***		1.72		17.82 ***		3
	Reference: Older									
	Similar		1.15		11.94 ***		1.04		11.94 ***	
			(0.1259)		(0.6353)		(0.1238)		(0.635)	
	Younger		1.14		2.55		1.06		2.55	
			(0.1153)		(0.6155)		(0.1158)		(0.6155)	
	QNA		0.55		10.21		0.49		6.06	
			(0.7355)		(22.954)		(0.6401)		(17.206)	
	Ethnic	12.78 ***		5.81 *		7.21 **		5.82 *		2
	Reference: Different									
	Same		1.46 ***		3.37 **		1.29 **		3.37 **	
			(0.1156)		(0.5039)		(0.1133)		(0.5033)	
	QNA		0.71		9		0.65		6.01	
			(0.4673)		(22.947)		(0.4338)		(17.248)	
	Wealth	14.15 ***		9.10 **		5.62		5.49		3
	Reference: Poorer									
	Similar		2.24 **		312.34 *		1.12		46.36	
			(0.3287)		(3.0755)		(0.2698)		(3.329)	
	Richer		2.49 ***		894.68 **		1.17		132.8	
			(0.3217)		(3.0463)		(0.2642)		(3.3111)	
	QNA		4.6 ***		11.74		2.1 **		4.39	
			(0.4197)		(33.87)		(0.3682)		(17.22)	
	Teacher-Fertilizer-Skills	6.11		4.62		5.71		4.62		4
	Reference: ExtAgents									
	Friends/Parents/Relat.		0.88		0.79		0.87		0.79	
			(0.101)		(0.2804)		(0.1006)		(0.2806)	
	Observing Others		0.76 *		0.86		0.85		0.86	
			(0.1527)		(0.6031)		(0.1511)		(0.6068)	
	Other		1.08		2.75		0.87		2.75	
			(0.1816)		(0.6162)		(0.1813)		(0.616)	
	QNA		0.54		0.77		0.42 *		0.77	
			(0.4433)		(0.4804)		(0.449)		(0.4805)	
Control: PA Characteristics	**Distancekm**		1.08 ***		0.99		1.1		0.99	
			(0.0179)		(0.0645)		0.0682		(0.0685)	
	PA.Diff.Lev		0.01 ***		0.19 **		0.002		0.19 **	
			(0.214)		(0.66)		(0.2284)		(0.6572)	
	MainCrop	140.14 ***		49.8 ***		33.54 ***		44.85 ***		6
	Reference: Barley									
	Cereals		21.91 ***		2.57		50.23 ***		2.57	
			(0.4726)		(1.6796)		(1.2473)		(1.6743)	
	Coffee		0.01		0.001		0.0007		0.0002	

		(14.91)	(14.88)	(15.34)	(23.2)
	Enset	7.65 ***	6.02	30.79 ***	6.02
		(0.7858)	(1.5915)	(1.1651)	(1.5774)
	Millet	6.1 ***	0.18	137.4 ***	0.18
		(0.4706)	(1.65)	1.1773	(1.6387)
	Teff	21.33 ***	0.05 **	295.4 ***	0.05 **
		(0.4785)	(1.5207)	(1.5866)	(1.5036)
	Wheat	13.05 ***	0.04 **	238.7 ***	0.04 **
		(0.325)	(1.3707)	(1.0759)	(1.3758)
Frailty	Theta			0.66 **	6.9e-17
				(0.2997)	(1.03e-09)
LCV		0.7118	0.3151	0.6957	0.3154
No. observation		4369	3692	4369	3692

Note: *** p < 0.01 , ** p < 0.05 , * p < 0.1

Table 5: Cox proportional hazard model and shared frailty model on adoption of fertilizer for two time periods each. All estimations have been performed using the R frailty package by Rondeau and Gonzalez (2005) and Rondeau et al. (2012) on the basis of the ERHS.

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