Original Article

The Long Shadow of Faith-based Social Networks on Agricultural Performance: Evidence from Ethiopian Apple Growers

Sintayehu Hailu Alemu[a,b,*], Luuk van Kempen[b] and Ruerd Ruben[b,c]

[a]Department of Economics, Hawassa University, P. O. Box 05, Hawassa, SNNPRS, Ethiopia.
[b]Department of Cultural Anthropology and Development Studies & Radboud Social Cultural Research, Radboud University , P. O. Box 9104, Thomas van Aquinostraat 6, 6500 HE Nijmegen, The Netherlands.
E-mail: l.vankempen@maw.ru.nl
[c]Wageningen Economic Research, Wageningen University, P. O. Box 29703, Alexanderveld 5, 2502 LS The Hague, The Netherlands.
E-mail: r.ruben@maw.ru.nl

*E-mails: s.alemu@maw.ru.nl; sintayehu2007@gmail.com

Abstract The aim of the paper is to test the importance of social networks in the acquisition of technical know-how among apple growers in Southern Ethiopia. What contribution do social networks make in knowledge transfer alongside more formal sources such as training and education? We take special interest in the role of faith-based networks, as apple cultivation was originally introduced into the study area by individuals and organizations linked to the Protestant church. The network effect is proxied by the frequency of contact of an individual producer ('ego') with his/her most salient resource persons ('alters') as well as the number of visits to their orchards. We find a positive relation between both types of social interaction and knowledge acquisition, although the efficacy of these varies with the producers' level of education. Protestant producers have been able to maintain a knowledge advantage with respect to Orthodox Christian producers ever since apple cultivation took off in the 1990s.

L'objectif de cet article est de tester l'importance des réseaux sociaux pour l'acquisition de connaissances techniques chez les producteurs de pommes dans le sud de l'Éthiopie. Quelles sortes de contributions apportent-ils aux transferts de connaissances, mis aux côtés de sources plus formelles telles que les formations professionnels et l'éducation? Nous portons un intérêt particulier au rôle des réseaux religieux, car la culture de la pomme fut initialement introduite dans la zone de recherche par des individus et organisations liées à l'église protestante. L'effet des réseaux est dépendent sur le nombre de visites à d'autres vergers et sur la fréquence du contact entre un producteur individuel (« ego ») avec ses personnes-ressources les plus saillantes (« alters »). Nous trouvons que les deux types d'interactions sociales ont un effet positif important sur l'acquisition des connaissances, bien que leur efficacité varie selon le niveau de formation des producteurs. Les producteurs protestants ont pu maintenir un avantage par rapport aux chrétiens orthodoxes depuis que la culture de pommes a décollé dans les années 1990s.

The European Journal of Development Research (2017). doi:10.1057/s41287-017-0094-3

Keywords: social networks; tie strength; peer effects; knowledge transfer; exclusion; religion

Introduction

There is broad consensus on the importance of agricultural product and process innovations in improving the livelihood and welfare of smallholder farmers in developing countries. Among the many exemplary cases, the Green Revolution stands out as a success story for improving

productivity and income levels among farmers in, most notably, South Asia. A number of studies have also identified the determinants of adopting various agricultural innovations in different parts of the world. In this literature, the role of social networks in shaping people's adoption decisions has recently received significant attention. However, fewer studies address social network influences on the agricultural performance among those who already adopted the innovation. We feel that this may be unwarranted, as a product innovation comes with a 'technological package' that needs to be understood and mastered. Adopters may differ in their position on this learning curve depending, among others, on their degree of access to the required knowledge about the package. Poor access likely implies suboptimal returns and, consequently, lower household income. It is conceivable that knowledge on how best to implement a new opportunity does not circulate freely, especially in rural areas of low-income countries, as information failures tend to abound. Rather, this knowledge may be caught up in a specific social network, notably that which is linked to the innovation source. If circulation is indeed restricted in the sense that 'leakage' from this network is minimal, being part of it is key for livelihood improvement among adopters.

We empirically test the importance of social network connections for adopters of apple in the Southern Ethiopian highlands. Apple had been virtually unknown to Ethiopian farmers until the 1990s, when a Pentecostal church as well as World Vision, a global NGO with an Evangelical Christian mission, started to promote it in the isolated district of Chencha.[1] Adoption of apple cultivation as a cash crop activity is now widespread in the highland area around Chencha, but knowledge on 'best practice' cultivation and marketing methods concerning both apple fruits and apple seedlings varies markedly among producers (Alemu *et al*, 2017). The seedling business, in particular, is knowledge-intensive. It has been established across four apple production centers in Chencha district, which coincide with the localities that are surveyed in this study, that better 'know-how' boosts output and yields higher quality seedlings, thereby generating higher incomes for farmers. A positive income effect from better knowledge can also be appreciated in fruits, but is more indirect, as high-quality production increases access to farmer cooperatives, who are better integrated with the market and thus secure (higher-priced) demand (ibid.).

The work by anthropologist Dena Freeman (2012) provides a lead as to what type of social network is potentially relevant in understanding the spread of knowledge on apple (seedlings) cultivation in the area. Her ethnographic account of apple adoption, and its economic and social consequences, in the locality of Masho, points to a key role for social networks formed among co-religionists, in this case of Orthodox Christians and Protestants.[2] At the time of introduction, the latter were presumably closer to the source of 'know-how' on apple, i.e., the *Kale Heywet* (Pentecostal) church and World Vision, which together provided the bulk of planting materials and technical training. Assuming that Protestant adopters enjoyed a head-start, as suggested in Girmay *et al* (2014) by stating that initially there was a "strong attachment of apple cultivation to the protestant religion" (p. 169), the question is whether Protestant producers still maintain a knowledge advantage over Orthodox producers today.

A complicating contextual factor is that the area has seen a high rate of conversion from Orthodox Christian to Protestant since the 1990s, such that Protestantism is no longer the small minority cult it had been in the preceding decades. We draw on Freeman (2012) to understand the complex interaction between Protestantism and apple cultivation in a historical perspective. She recounts that a small group of early converts to Protestantism, or more accurately, to Pentecostalism, developed a more entrepreneurial mindset under the influence of church teachings in the 1970s and 1980s; they were only able to exploit this attitudinal transformation when apple presented itself as a cash crop in the late 1990s. They quickly jumped on the bandwagon and proved commercially successful. In a bid to emulate this economic success,

many other community members started to adopt apple and switched allegiance to the Pentecostal church. Freeman's (2012, pp. 174–175) reconstruction of this wave of religious conversion runs as follows:

> .. When the wealth potential of the apple business had become clear, traditional, non-Pentecostal men started to join in too … However, as soon as they generated a surplus they found that kin and community started to demand a share of their wealth, most particularly through demands for them to become *halak'a* [a position of prestige derived from sponsoring lavish community feasts]. In this situation, and seeing how their Pentecostal neighbours were able to keep their own money and spend it as they pleased, many people decided to join the [Pentecostal] church … The conversion was sudden and dramatic and coincided exactly with the apple boom. This might sound like an overly utilitarian understanding of the attractions of Pentecostalism, but the timing cannot be a coincidence.

The argument that religious conversion served the purpose of effectively evading strict kin-based or communal sharing norms is undoubtedly a very pertinent one and has been documented across Sub-Sahara Africa (see Platteau, 2009). It also fits in with recently gathered evidence on the importance of the so-called 'kin tax' in various African settings (Di Falco and Bulte, 2011; Jakiela and Ozier, 2016; Grimm *et al*, forthcoming). This paper, however, investigates whether becoming part of the Protestant community served apple adopters, intentionally or unintentionally, in yet another way, i.e., through tapping into Protestants' superior knowledge on apple (seedling) cultivation. This question is a pertinent one, because so far the evidence on the importance of religious social networks in agricultural innovation is mixed in the Ethiopian setting (Mekonnen *et al*, 2016; Todo *et al*, 2011).

The empirical test is based on survey data from 380 apple producers, of which close to 80 per cent identified as Protestant at the time of fieldwork (2013), while almost all others were Orthodox Christians. Before presenting the results from the survey data, which are obtained from regression analysis, we review the literature on social networks and extract the most relevant concepts for our purposes in Section "The Role of Social Networks in Knowledge Transfer." The study area is introduced in Section "Materials and Methods," as well as the sampling strategy, the empirical model to be tested, and the measurement of the variables in the model. Section "Results and Discussion" is the core of the paper, in which both network and non-network effects are reported and discussed. Finally, Section "Conclusions" summarizes the argument and offers policy reflections.

The Role of Social Networks in Knowledge Transfer

The adoption literature acknowledges the importance of social networks and the behavior of other farmers in the process of technology diffusion (Bandiera and Rasul, 2006; BenYishay and Mobarak, 2014; Conley and Udry, 2010; Ellison and Fudenberg, 1993; Feder *et al*, 1985; Krishnan and Patnam, 2014; Matuschke and Qaim, 2009; Songsermsawas *et al*, 2014; Van den Broeck and Dercon, 2011). The empirical studies can roughly be classified into those that consider social network effects on the adoption decision as such versus those that deal with social (learning) effects in a bid to explain heterogeneity among adopters on various outcomes, such as level of technical and economic efficiency, and product quality. Examples of the first set of studies include Ellison and Fudenberg (1993), who modeled the role of neighbors' experience in deciding which technology to use, and Matuschke and Qaim (2009), who considered the impact of social networks on hybrid seed adoption in India. The latter study provides empirical support for the idea that a farmer's social network plays an important role in technology adoption decisions. Bandiera and Rasul (2006) analyze how social learning links

Mozambican farmers' initial decisions to adopt a new crop (sunflower) to the decisions of others in their social network. They found that social effects are positive when there are few adopters in the network, but negative when there are many. The explanation for this counterintuitive finding is that having many adopters in the network increases incentives to delay adoption strategically and free ride on the knowledge accumulated by others, resulting in a U-shaped relation between likelihood of adoption and the number of adopters in one's network. In their review of empirical adoption studies, Feder *et al* (1985, p. 288) recognize the importance of "social institutional environments," alongside economic factors, in explaining the success or failure of agricultural innovations.

In the second set of studies, the role of social networks as facilitators of information flows in adoption processes is more directly illustrated. A good example is the case study by Van den Broeck and Dercon (2011) on banana producers in Tanzania. Considering farmers' kinship group, neighbors, and members of informal insurance groups, the authors showed that information flows exist within all types of groups considered, but output externalities are limited to kinship groups. Other important contributions in this respect include Conley and Udry (2010) and Krishnan and Patnam (2014). The first study presents evidence that social learning is important in the diffusion of knowledge, focusing on farmers' decisions about the intensity of input use (fertilizer and labor) in pineapple production in Ghana. They find evidence that farmers adjust their inputs to align with those neighbors who were surprisingly successful in previous periods. The second considers the adoption of inputs (fertilizer and improved seeds) using panel data from Ethiopia between 1999 and 2009. It compares the learning process from extension agents with that from neighbors. While the initial impact of extension agents was high, the effect wore off, in contrast to learning from neighbors, which persisted. Hence, social learning proved to have a more lasting influence on decision-making than the formalized type of knowledge transfer. This resonates with the peer effect study by Songsermsawas *et al* (2014) on agricultural productivity in India, which estimated that peer effects explain 60 per cent of the variation in farmers' revenue. They also find that peer effects are strongest when it concerns the cultivation of new crops. In a similar vein, BenYishay and Mobarak (2014) reveal in a large-scale field experiment in Malawi that farmers reckon social networks the most credible source of newly arrived know-how. Our paper contributes to the second set of studies by assessing knowledge heterogeneity among apple adopters in relation to social networks.

Taking a social network perspective directs attention to the notion that individuals are not acting in isolation but are "embedded" in a network of social relations (Granovetter, 1983). Individual actors (egos) in interaction with their network partners (alters) usually engage in exchange of information, material and immaterial goods, and services (Bernardi, 2011). The strength of relationships between the ego and his alters varies across relationships, which depends, among others, on its duration, emotional intensity, level of intimacy, and the reciprocal services that tie these individuals together (Granovetter, 1983). Social network research distinguishes between two types of relationships depending on their strength: weak and strong ties (Friedkin, 1982; Granovetter, 1973). Even though there is no 'natural' boundary that differentiates alters in these two categories, the existing literature tends to categorize family and friends as strong ties, whereas neighbors and acquaintances are considered weak ones (Bernardi, 2011). Granovetter (1983) maintains a slightly different categorization, where neighbors are still considered strong ties, whereas 'friends of friends' are considered weak ones.

The seminal work by Granovetter (1973) compares strong and weak ties. He proposed that weak ties are usually more important than strong ties in understanding network-related issues. His original claim was that a network made up of strong ties is not the most appropriate channel for innovation. His reasoning was based on the assumption that strong ties tend to bond similar

people together and the information obtained through such a tie tends to be redundant. By contrast, weak ties usually constitute a "local bridge" to parts of the system that are otherwise disconnected, and thus likely provide new information from disparate parts of the system (Krackhardt, 1992). Therefore, it follows that weak ties offer a superior contribution in terms of information transfer.

Granovetter (1983) later refined his proposition and came up with a curvilinear prediction. When tie strength increases, the access to relevant information will also increase, but once it passes some threshold, the potential for information transfer falls again due to similarity. In a subsequent paper (1985), he explains that weak ties provide people with access to information and resources beyond those available in their own social circles, yet strong ties entail greater motivation to assist one another, and are typically more easily available. Strong ties constitute a base of trust that can reduce resistance and provide comfort in the face of uncertainty. It can thus be argued that change is not facilitated by weak ties, but rather by a particular type of strong ties (Krackhardt, 1992). Weak ties, although sufficient for locating information, can be insufficient for moving complex information. Therefore, we probe what type of ties, strong or weak, contribute more towards knowledge acquisition in our sample of Ethiopian apple producers.

Social network theory also distinguishes between *neighborhood effects* and *peer effects* (Topa and Zenou, 2014), although it proves difficult to disentangle spatial proximity from social proximity empirically, as these overlap in most instances. Sharing the same environment and facing the same institutions tends to nudge people's behavior in the same direction. Neighborhood crime is the textbook example, where high levels of violence provoke a further escalation of violence. The notion of peer effects refers to the idea that average group behavior incentivizes individual group members to act in line with that behavioral norm. In sum, 'the probability of observing an individual behaving in a certain way is a function of either some characteristics of the individual's environment (neighborhood effects) or depends directly on the prevalence of this type of behavior among her peers (peer effects)' (Helmers and Patnam, 2014, p. 68).

Apart from considering different types of networks and relations, it is also pertinent to highlight the distinction in the literature on knowledge itself, which can be very explicit (tangible) or tacit (Howells, 2002; Mohammad *et al*, 2010; Polanyi, 1966). The main differences, according to (Ipe, 2003), are its degree of codifiability and its mechanism of acquisition, transfer, and accumulation. Polanyi (1966) argued that large part of human knowledge cannot be articulated and made explicit. It also cannot be codified and communicated easily and cannot be used in the absence of the knower (Ipe, 2003). On the contrary, explicit knowledge can easily be codified, stored somewhere, and transferred across time and space in the absence of the knower (Lam, 2000). It can be shared more easily than tacit knowledge. However, in many domains it is likely a combination of both types that create the critical mass of knowledge that enables individuals or organizations to achieve their objectives. Certain aspects about agricultural technologies, therefore, can be acquired from attending formal knowledge sources like education and training, but other pieces of information need to be gathered from the environment, own experience (learning-by-doing) and through social networks. The social networks can be friends, relatives, neighbors, or groups in a certain village, which may be tied to an institution, such as the Pentecostal church in our case.

Social network studies on agricultural performance in Sub-Sahara Africa tend to focus on ethnicity as a variable along which networks are formed, but religion nevertheless features in some of them. For instance, the aforementioned study by Bandiera and Rasul (2006) on the adoption of sunflower in Mozambique found that adoption choices are positively correlated within religious networks, but the marginal effect of having an additional adopter among family and friends is larger than having one among co-religionists. Religion even appears to be an

irrelevant factor in the case of new technology diffusion among pineapple growers in Ghana, as studied by Conley and Udry (2010). They report "no evidence that religion influences information links" (p. 47). In a recent social network study in Ethiopia on the adoption of row-planting techniques in maize, wheat, and *teff*, the influence of religious connections also proves elusive (Mekonnen *et al*, 2016). Among the 379 farmers surveyed across the Oromia region, religion is not strongly associated with the adoption of row planting. In fact, the authors claim that only social networks geared towards professional exchange are useful in spreading agricultural knowledge, and recommend that such networks be built by development actors instead of harnessing already existing networks that primarily serve a social function. This advice runs in contrast to the findings of an earlier study by Todo *et al* (2011) in the Arsi zone of the same region in Ethiopia. Their social network elicitation among 281 farmer households of wheat, barley, fababean, maize, and potato reveals "a significantly positive role of religion, rather than ethnicity, in forming general social networks" (p. 11), which in turn promotes knowledge diffusion on best agricultural practices (conservation tillage, fallowing, composting, crop residue management, high-yielding varieties, and crop rotation). Provided the social network is characterized by geographical proximity and a high frequency of interaction, this improved knowledge is shown to translate into enhanced adoption as well.

Figure 1 summarizes our analytical framework, indicating how the overall level of knowledge of a farmer, which likely consists of a mix of codified and tacit knowledge, can be enhanced through both formal and informal sources. Some sources are intimately linked to a particular type of knowledge, e.g., formal training to codified knowledge, and experience (learning-by-doing) to tacit knowledge. We posit that social networks contribute to both; verbal communication between peers requires some level of codifiability, albeit substantially lower than in the case of training, while the more observational component seems especially conducive to spread tacit knowledge.

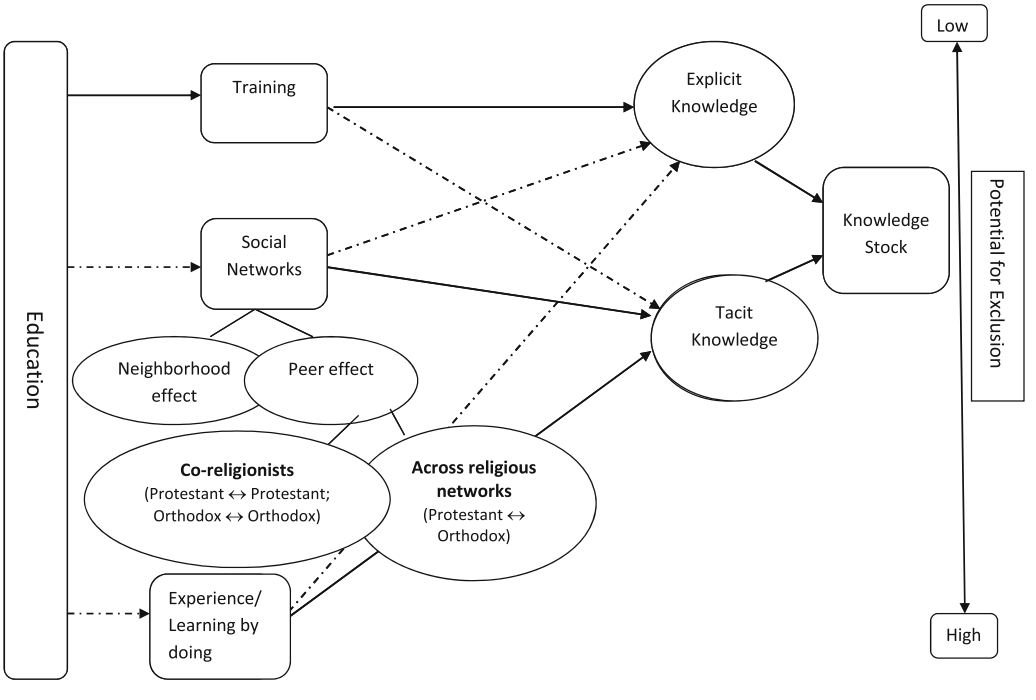

Figure 1: Sources of knowledge for 'lagging' producers and their corresponding potential for exclusion.

In Figure 1, a solid (dotted) line indicates that the contribution of a source to a given type of knowledge is supposed to be strong (weak). Note that formal education is incorporated in the scheme as an indirect source of knowledge, as the curriculum does not deal with apple cultivation as such, but having been to school likely increases the efficiency with which knowledge can be extracted (and absorbed) from direct sources. This complementarity is assumed to be strongest in the case of formal training, as this type of knowledge dissemination may include sessions that resemble a typical classroom setting and literacy skills may be required. Still, we conjecture that exposure to education is also helpful in gaining knowledge from social networks and more efficient learning-by-doing, if only because school experience strengthens information processing skills. A final remark concerning Figure 1 is that, towards the bottom of the scheme, the spread of knowledge tends to become more exclusionary, at least potentially, which stems directly from its increasingly tacit nature. On this dimension, social networks take an intermediate position between formal training on the one hand, where exclusion can occur in the form of non-invitation but where it is hard to exclude those invited from gaining the knowledge offered, and experience on the other. Those who have privately gained knowledge through experiential learning can relatively easily withhold it from latecomers and may not even be capable of transmitting the (non-codifiable) knowledge if they wanted to. At the same time, social networks seem more "leaky" when it comes to disseminating knowledge, as social interaction is often diffuse and hard to control. Still, exclusion may be a strong defining feature of social life, especially across different networks. Even demonstration effects through mere observation may be minimized, such as in our apple case, where orchards tend to be fenced enclosures around the homestead to prevent theft of valuable apple seedlings. We purport to test this framework empirically, as far as our data allow, for apple producers in Chencha.

Materials and Methods

Data and Measurement

The data were collected from 380 apple (and apple seedling) producers in Chencha district in 2013. The district is located in the Gamo Gofa zone of the country's Southern Nations, Nationalities and Peoples' Region (SNNPR) and has a total area of 37,650 ha, situated at an altitude ranging from 1600 to 3200 masl with an average annual rainfall of 1100–1300 mm. The mean annual temperature is around 17 °C (min 11 °C to max 23 °C). The district is characterized by mixed systems farming based on crop production and livestock rearing. The cereals most commonly grown in the area are wheat and barley, while beans and peas are the most popular leguminous crops. Potato and *enset* (false banana) are the dominant root crops in the area. Cash crops are few, of which apple is very dominant. Apple orchards are estimated to cover 728 ha in total (Fetena *et al*, 2014). In terms of livestock ownership, cattle, sheep, horses, mules, and chickens feature most prominently. According to a recent study by Eshetu and Mekonnen (2016) on poverty in Chencha district and the adjacent (low-land) district of Mirab Abaya, livestock ownership is an important predictor of poverty. The same applies to land ownership. Most households (84 per cent) possess landholdings in the range of 0.1–0.5 ha only, which attests to high population density. Using a poverty line of 250 Birr per adult equivalent per month, the poverty rate is calculated to equal 30 per cent of households (ibid.).

In order to determine a suitable sample, we approached the agricultural office in the district and identified sub-districts (*kebeles*) that were important centers of production and marketing of apple (seedlings). From a total of 50 *kebeles,* the following nine were identified as such by key

informants: Doko Shaye, Doko Losha, Doko Masho, Ezo, Elena Chare, Mafona Zolo, Doko Kale, Tolola, and Chencha town. All are rural localities, except for urban Chencha and peri-urban Tolola. Applying a maximum variation sampling strategy on the rural–urban continuum, Chencha town and Tolola were selected in addition to two randomly chosen rural *kebeles*, viz. Doko Shaye and Doko Losha. The development agents held a registry of all apple farmers in these localities. Rather than sampling farmers from this list, all were included in the study and presented with the survey. Hence, the sampling procedure combined purposive sampling (at *kebele* level) with a census of apple farmers in the selected clusters. The number of observations per *kebele* ranges from 77 to 101.

The collection of social network data used the name generator method. Farmers were asked to name their three most important resource persons when it comes to the cultivation of apple, excluding professionals like extension workers. Most were able to mention three (72 per cent), while others could only mention one (18 per cent) or two (10 per cent). We will refer to the first-mentioned alter as 'the most salient,' given that respondents were asked to start with the one of highest importance. Then the 'egos' were solicited to provide the following information on each of the listed members of their social network ('alters'): age, gender, education level, main occupation, religious affiliation, years of acquaintance, frequency of contact per month, and the type of personal relationship. Moreover, they were asked additional questions related to their information source to get a more complete picture of how social networks contribute to the level of knowledge on apple cultivation and to cross-check the information solicited in the name-generating exercise. These questions included whether they sourced information outside or inside their village, whether they had sufficient information on apple to cultivate it in a satisfactory way, whether they felt part of the network of knowledgeable producers, whether others kept the knowledge on apple cultivation secret from them, and, finally, whether they themselves kept the knowledge secret from others.

The strength of a network tie is proxied by the frequency of contact (per month) of the ego with his/her alter. In defining the cut-off between weak and strong, we use Granovetter's (1973) rule of thumb, which states that weak ties are those relations in which ego and alter interact more than once a year but less than twice a week. Those egos who have contact with an alter on at least 8 days in a month were treated as being strongly tied, whereas contact on fewer than 8 days per month implies a weak-tie relationship. We use this binary variable of tie strength in the regression analysis, but also test an alternative specification in which frequency of contact is taken up as a continuous variable.

The degree of knowledge is measured by evaluating farmers' knowledge in six domains: variety identification, grafting, pest control, fruit tree management, postharvest handling, and marketing. This measurement approach is inspired by Hussain *et al* (1994), but whereas this study awarded binary (true or false) scores to the respondents, we opt to assess the farmer's knowledge in each domain on a five-point (Likert) scale, i.e., from 'very poor' to 'very good,' based on anchoring vignettes developed in cooperation with local extension agents. The actual assessments were also done by an extension agent working in the locality, who was hired for this interviewing task. Our measurement is arguably more sensitive to (subtler) variations in the level of knowledge among the producers than dichotomous scoring. Based on these scores per domain an overall knowledge index has been generated using principal components analysis. The first principal component, having an eigenvalue greater than one, has been used in the regressions. Details on the principal components analysis (KMO and Cronbach's Alpha tests) are presented in Tables A8 and A9 of Appendix.

The education, experience, and training variables are quantified as follows. A first education variable is measured in years of formal schooling attained by the producer, while a second one

records the highest grade completed (maximum education). The experience of the producer on apple cultivation was also measured in years starting from the years/he adopted apple to the year when the survey was conducted. The training variable is captured by two dummy variables, one for pre-adoption training and one for post-adoption training, depending on the timing of the apple-specific training in relation to the moment of adoption. Both dummies take the value 1 if the producer attended the training.

Method of Analysis

Our method of analysis is based on Matuschke and Qaim (2009), which in turn follows the model of learning by Bandiera and Rasul (2006). They used this model for analyzing the impact of social networks on the adoption of an agricultural innovation per se, but we have modified it for our purposes. Birkhaeuser *et al* (1991) argue in their study on the impact of extension services on knowledge acquisition among adopters that they have an advantage over adoption impact studies, due to the fact that adoption is dependent in part on transitory factors (e.g., shortage of certain complementary supplies, credit, prices) that may vary across locations and may, as a result, bias estimates of the impacts of extension efforts. Knowledge acquisition among actual (rather than potential) producers is not hindered by such problems, at least not directly, and therefore arguably produces a more reliable assessment of the effectiveness of extension. Our approach enjoys the same advantage, as it does not rely on adoption decisions for identification.

Since we did not specifically evaluate the knowledge of peers, we unfortunately cannot control for the endogenous network effects put forward by Bramoullé *et al* (2009), Manski (1993), Matuschke and Qaim (2009), and Songsermsawas *et al* (2014). These studies highlight that the alters' level of knowledge affects the knowledge of the egos, which feeds back into the network to affect others' expertise and so forth. Therefore, our model only captures exogenous network effects. The explanatory variables in the regression cover most of the variables included in Feder *et al* (2004) and Hussain *et al* (1994). Others have been added, such as cooperative membership, disaggregated training into pre-and post-adoption, and religion, which seem potentially relevant in the context of our case.

The level of knowledge (K) of a producer (i) on apple cultivation is expressed as

$$K_i = \beta X_i + \delta X_{n(i)} + \theta T_i + \alpha W_i + e_i.$$

The level of knowledge of the farmer depends on household characteristics of the producer (X_i), household characteristics of his network ($X_{n(i)}$), tie strength (T_i), and other explanatory variables (W_i) like experience and training. The religion of the farmer, location dummies, and the interaction of religion with experience and training of the producer are included in the empirical model as well. The β, δ, θ, and α are vectors of parameters that are estimated corresponding to the vector of variables X, X_n, T, and W, respectively.

Results and Discussion

A Profile of Egos and Their Alters

We have collected social network information from 886 alters belonging to 380 egos. The descriptive statistics in Table 1 show that the average age of alters coincided with that of egos (44 years). The average family size in the surveyed villages was 6.2 individuals per household.

Table 1: Descriptive statistics on egos and alters

Variable	*Obs.*	*Mean*	*Std. dev.*	*Min.*	*Max.*
Alter characteristics					
Age	886	44.63	13.58	16	80
Education (in years)	858	10.60	4.62	0	22
Gender (1 = female)	886	0.014	0.12	0	1
Duration of bond (in years)	886	13.38	11.08	0.25	60
Frequency of contact per month	885	11.28	10.45	1	30
Ego characteristics					
Age	380	44.20	13.97	16	95
Education in years	380	7.79	4.64	0	16
Gender of head (1 = female)	380	0.12	0.32	0	1
Religion (1 = Protestant; 0 = other)	380	0.79	0.41	0	1
Cultivation experience	380	10.52	5.47	1	34
Pre-adoption training	380	0.25	0.43	0	1
Post-adoption training	380	0.48	0.50	0	1
Number of visits to others' orchards	380	9.45	28.27	0	300
Knowledge index component 1	380	0.00	1.99	−4.38	4.45
Cooperative membership	380	0.81	0.40	0	1
Total fruit production in kg	380	307.1	527	1	3923
Total seedling production in number	314	711.8	1065	5	8150
Family size	380	6.20	2.51	1	14
Sub-district (Kebele) Dummies					
Dummy for Doko Shaye	380	0.27	0.44	0	1
Dummy for Doko Losha	380	0.27	0.44	0	1
Dummy for Chencha Town	380	0.20	0.40	0	1
Dummy for Tolola (base category)	380	0.27	0.44	0	1

Both egos and alters were predominantly men (88 per cent of egos and 98 per cent of alters). The average level of formal education attained by alters (egos) was 10.6 (7.7) years (see Table A2 in annex for details), whereas the average length of the personal relationship between egos and alters was reported to be 13.4 years and the frequency of contact per month among them was 10.5 days on average. 79 per cent of the egos in the sample are Protestants, while the remaining 21 per cent are mostly Orthodox Christians, with a few exceptions (see Table A3 in annex for details). The alters mentioned by egos as key information source include a group of 30 highly connected individuals, 10 of which are mentioned by more than 11 egos. They tend to be the central resource individuals who connect at least 368 producers from the total of 886 alters mentioned as network contacts of apple producers in the surveyed localities. The most frequently mentioned alter is reported by no less than 51 egos. Some alters (14 out of the 30 central ones, or 47 per cent) were mentioned across villages, while the remaining ones were only mentioned in their respective home villages. Most alters were categorized as friends (62 per cent), followed by kin (16 per cent) and family (7 per cent), which leaves 15 per cent as non-categorized others (see Table A4).

The distribution of the knowledge level of respondents is presented in Figure A2 of the annex. Most respondents (30–50 per cent) have an average level of knowledge and the rest have relatively symmetric distribution for high and very high combined versus limited and very limited combined categories. There is also considerable variation on the level across the knowledge categories. For example, there are few individuals who have the ideal high score for pest control methods whereas relatively the highest number of respondents for the knowledge category of fruit tree management for the same score. The producers have on average 10.5 years of apple cultivation experience. Per year the average producer harvests 307

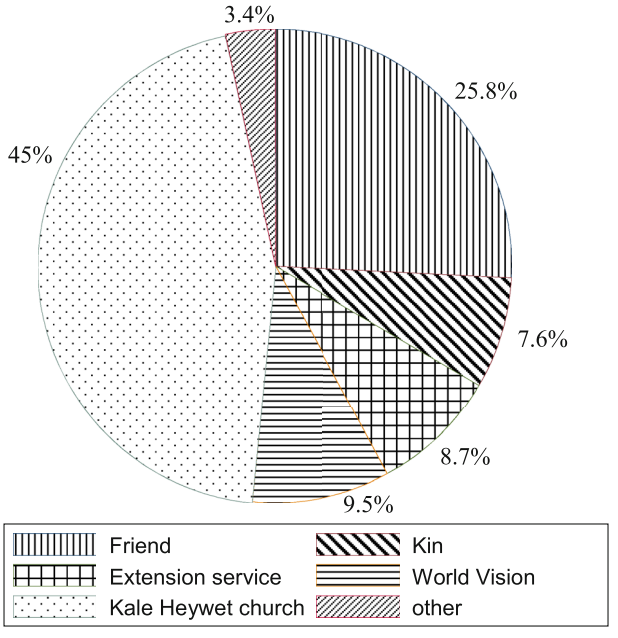

Figure 2: Most important source of information on apple cultivation at time of adoption.

kilograms of apple and obtains 712 grafted seedlings. 81 per cent of the surveyed producers are member of one of the nine apple fruit and seedling marketing cooperatives operating within the district. Out of the total pool of producers interviewed, a quarter received training on apple cultivation prior to adoption. This share nearly doubles (48 per cent) when post-adoption training is considered. Producers on average visited nine orchards of other producers during the production season that preceded the survey. When they were asked whether other apple producers keep techniques of apple production secret from them and whether they themselves also hide their knowledge from others, 35 per cent of the producers confirmed secrecy on the part of others, while, interestingly, only 5 per cent admitted to keeping information for themselves. Assuming a downward bias on the second question due to social desirability, the data hint at a substantial degree of (deliberate) exclusion. This raises the question how important informal sources of knowledge are considered to be compared to formal ones. As shown in Figure A1, over 60 per cent of the egos indicated that informal contacts were the prime source of knowledge at the time of the interview, mostly friends (50 per cent). The *Kale Heywet* church stood out among the formal sources (24 per cent), followed by extension agents (13 per cent) and World Vision (3 per cent). From Figure 2, which shows the knowledge sources at the time of adoption, it can be observed that informal sources have become more important over time, as they only accounted for about a third of responses at adoption. Farmers used to rely heavily on the *Kale Heywet* church (45 per cent) and to a lesser extent on World Vision (10 per cent) and extension agents (9 per cent) when starting their apple business.

Determinants of Variation in Knowledge

Table 2 below shows the regression results on the first principal component of knowledge on different knowledge sources, ego and alters characteristics, network proxies, and village dummies. The columns only differ based on stepwise control of explanatory variables in the model.

Table 2: Regression of knowledge on producer and social network characteristics

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Ego & Alter characteristics					
Education of ego (in years)	0.170 (0.016)***	0.113 (0.015)***	0.055 (0.015)***	0.059 (0.015)***	0.084 (0.017)***
Education of alter (in years)	0.087 (0.014)***	0.043 (0.013)***	0.010 (0.012)	0.018 (0.013)	0.009 (0.013)
Ego's religion (1 = Protestant; 0 = other)	0.994 (0.147)***	0.756 (0.132)***	0.821 (0.131)***	0.829 (0.130)***	0.813 (0.129)***
Alter's religion (1 = Protestant; 0 = other)	0.196 (0.171)	−0.058 (0.153)	−0.026 (0.148)	0.051 (0.149)	0.076 (0.147)
Age of ego	−0.012 (0.005)**	−0.025 (0.005)***	−0.027 (0.004)***	−0.026 (0.004)***	−0.023 (0.004)***
Age of alter	−0.001 (0.005)	−0.008 (0.004)*	0.005 (0.004)	0.007 (0.004)	0.006 (0.004)
Gender of ego (1 = female)	0.182 (0.210)	0.139 (0.187)	−0.129 (0.179)	−0.098 (0.178)	−0.111 (0.176)
Gender of alter (1 = female)	0.178 (0.524)	0.466 (0.464)	0.254 (0.440)	0.178 (0.438)	0.187 (0.432)
Training and experience					
Experience		0.080 (0.011)***	0.079 (0.010)***	0.079 (0.010)***	0.076 (0.010)***
Training received (before)		0.535 (0.136)***	0.441 (0.141)***	0.454 (0.140)***	0.456 (0.138)***
Training received (after)		0.998 (0.114)***	0.999 (0.109)***	0.980 (0.109)***	0.948 (0.108)***
Network indicators					
Farms visited last season		0.013 (0.002)***	0.011 (0.002)***	0.011 (0.002)***	0.010 (0.002)***
Frequency of contact per month				0.016 (0.005)***	0.017 (0.005)***
Orchard visits * Education (1 = illiterate)					0.112 (0.022)***
Frequency contact * Education (1 = illiterate)					−0.009 (0.013)
Sub-district dummies					
Doko Shaye *kebele*†			−0.507 (0.194)***	−0.341 (0.199)*	−0.376 (0.198)*
Doko Losha *kebele*†			−1.542 (0.163)***	−1.463 (0.164)***	−1.461 (0.162)***
Chencha town†			−0.087 (0.145)	−0.066 (0.144)	−0.078 (0.142)
Constant	−2.628 (0.712)***	−1.680 (0.635)***	−0.692 (0.625)	−1.336 (0.651)**	−1.534 (0.643)**
F Statistic	44.83	58.25	59.77	57.40	54.05
Adjusted *R*-Squared	0.29	0.44	0.51	0.51	0.53
Number of observations	858	858	858	857	857

Note: The figures in parentheses represent the robust standard error. $^{+}p < 0.1$; $*p < 0.05$; $**p < 0.01$; † Reference category: Tolola.

Non-network Sources of Knowledge

One out of each four surveyed egos received pre-adoption training, which was offered by various actors. Table A1 of the annex shows that 52 per cent of them participated in training from the *Kale Heywet* Church, 33 per cent from World Vision Ethiopia, 9 per cent from the

public extension service of the Ministry of Agriculture, and the remaining 5 per cent from cooperatives and other NGOs working in the district like Agri-Service Ethiopia and VITA (Fighting Hunger and Climate Change in Africa). Almost half the sample received post-adoption training from, in order of importance, *Kale Heywet* church (47 per cent), World Vision Ethiopia (22 per cent), cooperatives (21 per cent), other NGOs (6 per cent), and the extension service (4 per cent). Since 10 per cent of the egos participated in training both before and after adoption, 38 per cent did not participate in any training. See Table A1 for an overview of participation in training. The training topics included both fruit tree management and seedling cultivation. Other topics like marketing, pest control, and related issues were only moderately covered in the trainings conducted.

As we can observe from the regression result in Table 2, the contribution of training to knowledge acquisition by the producer is very strong and highly significant at 1 per cent. Post-adoption training makes a stronger contribution compared to pre-adoption training. Attending a pre-adoption and post-adoption training improves the knowledge score of the producer by 0.46 and 0.95 points, respectively. This is likely due to the fact that producers understand the training better when they have some experience with the cultivation of the crop already.

The highest level of education achieved (in years) of the producer is also a strongly significant and positive driver behind the built-up of know-how. One additional year of education increases the knowledge score of the producer by 0.08 points. This indicates that educated producers have higher knowledge on the technology than their less educated counterparts, which may be explained by the fact that they have better understanding of the technical issues when they become experienced or attend trainings. Moreover, the knowledge of egos increases with the level of education of their alters, which foreshadows the presence of network effects. However, once we control for location (village), this effect loses significance.

Experience (in years) of the producer on apple cultivation is also a strongly significant determinant of farmers' knowledge. One additional year of experience improves the knowledge score by 0.08 points, suggesting that producers update their knowledge on the optimum combination of inputs and the general management of the crop based on experimentation.

Social Networks as Knowledge Brokers

The explanatory variable with the second most important contribution to knowledge, i.e., after post-adoption training, is the religious affiliation of the ego. Protestant producers have a 0.81 points higher knowledge score compared to producers of a different religious denomination (almost exclusively Orthodox Christians), which sheds light on our main research question. Information sharing is not restricted to one's own religious group, although a certain in-group bias can be observed. Ninety per cent of the alters of Protestant egos are fellow Protestants, whereas their share in the total population of apple producers is below 80 per cent. Vice versa, the alters mentioned by the Orthodox egos are fellow Orthodox Christians in about 35 per cent of the cases, which exceeds their actual share of 20 per cent in the (producer) population by a substantial margin (see Tables 3, A3).

The frequency of contact per month of the ego and alters has a positive and significant relation with the knowledge scores. One more contact per month between the egos and alters increases the knowledge score of the ego by 0.017 points. This suggests that the strong ties contribute more towards better knowledge of the farmer than the weak ones. However, this relation is limited to the network of educated egos, as indicated by the negative sign of the interaction term of frequency of contact and the literacy dummy (1 for educated egos, 0 for non-educated egos) at the bottom of Table 2. The interaction of the frequency of contact and the religion dummy variables is positive and significant,

Table 3: Religious affiliation of alters, by religion of egos

	Tie 1		*Tie 2*		*Tie 3*	
	n	%	*n*	%	*n*	%
For orthodox egos						
Orthodox Christian	21	28	28	43	20	32.3
Protestant	53	70.5	37	57	41	66
Muslim	1	1.5	–	–	1	1.7
Total	75	100	65	100	62	100
For protestant egos						
Orthodox Christian	30	11	24	11	14	7.6
Protestant	241	89	193	88.5	171	92.4
Muslim	–	–	1	0.5	–	–
Total	271	100	218	100	185	100

indicating that the social interaction among Protestants is more intensive than among the Orthodox Christians. We also ran a separate regression replacing tie strength in terms of frequency of contact per month (continuous variable) by a dummy for strong and weak ties. The results, displayed in Table 4, indicate that strong ties contribute 30 per cent more than the weak ties towards improving the knowledge of the producer. This reveals that learning becomes more intense when the bond between the ego and alter is stronger. As mentioned, we did not measure the knowledge of alters directly, since the information about alters was collected from egos only.

A similar positive and significant result has been found for the number of visits that ego has effected to the orchards of his or her alters (confined to the three most important resource persons). An additional visit improves the knowledge score of the producer by 0.01 point. Visual inspection, such as observing the spacing of apple trees, plausibly helps to copy the best practices from network members and possibly complements or strengthens what has been acquired from formal trainings and own experience. The positive sign of the interaction term for the number of visits and the education dummy for the egos shows that observation is more important for the illiterate egos compared to the literate ones.

Other Factors

The age of the producer is the only negative and significant variable in the model. An additional year in age reduces the producer's knowledge score by 0.02 points. However, we should be careful to infer that young producers are on average more knowledgeable than the elderly on apple cultivation, as experience turned out to be a positive determinant of knowledge as well. Young producers do better than older farmers in case they have the same level of experience, but experience and age are positively correlated, albeit modestly so ($r = 0.26$, $p < 0.01$). Finally, the village where a producer resides turns out to be a significant determinant of knowledge. The three villages, Doko Shaye, Doko Losha, and Chencha town, have limited knowledge on apple technology compared to Tolola village (omitted in Table 2 as base category). The latter hosts more knowledgeable famers on average, which can plausibly be attributed to the fact that apple was originally introduced here and was the center of early adopters.

Tables A6 and A7 of Appendix are presented as a robustness check based on averaging the peer attributes in every group and controlling for interaction effects of training, experience, and religion. The results are similar to what has been presented in the subsections on results above.

Table 4: Regression of knowledge on tie strength and other controls

Variable	*Knowledge*	*Knowledge*
Tie strength (1 = strong; 0 = weak)	0.305	0.307
	(0.109)**	(0.109)**
Level of education completed in years by Ego	0.058	0.060
	(0.016)**	(0.015)**
Level of education in years of Alter	0.026	0.026
	(0.013)*	(0.013)*
Dummy for ego religion	0.875	0.871
(1 = protestant; 0 = other)	(0.134)**	(0.134)**
Dummy for alter religion	0.087	0.103
(1 = protestant; 0 = other)	(0.152)	(0.150)
Age of Ego	−0.029	−0.029
	(0.004)**	(0.004)**
Age of Alter	0.007	0.007
	(0.004)$^{+}$	(0.004)$^{+}$
Gender of Ego (1 = female)	−0.137	
	(0.183)	
Gender of Alter (1 = female)	−0.032	
	(0.448)	
Experience	0.079	0.078
	(0.011)**	(0.011)**
Post-adoption training	1.071	1.069
	(0.111)**	(0.111)**
Doko Shaye *kebele*†	−0.147	−0.159
	(0.196)	(0.194)
Doko Losha *kebele*†	−1.532	−1.517
	(0.168)**	(0.167)**
Chencha Town†	−0.006	−0.004
	(0.147)	(0.146)
Constant	−1.316	−1.539
	(0.657)*	(0.375)**
F statistic	58.97	68.87
Adjusted R-squared	0.49	0.49
Number of observations	858	858

Note: The figures in parenthesis represent the robust standard error. $^{+}$ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; † Reference category: Tolola.

We also controlled for wealth and asset index to check the effect, if any, on apple cultivation knowledge but came out insignificant and dropped from the model.

Conclusions

Apple cultivation has become an attractive livelihood option in Chencha, Ethiopia, but due to incomplete knowledge on cultivation techniques a large group of farmers, despite their location in a suitable agro-climatic zone, is not in a position to reap the same level of benefits as the most knowledgeable producers. In part this stems from lower participation in formal trainings and from being late adopters, which implies less experiential knowledge through learning-by-doing, but it is also a consequence of being "far" from the knowledge source, both socially and geographically speaking. On the latter two aspects, we find that the social network effect represented by the number of visits to others' orchards, the frequency of contact between the

ego and alters, and, most strikingly, the religion of the ego bear a positive and significant association with the knowledge of the producer. It is relevant to point out that visiting the orchards of other producers proves more effective for illiterate egos, while the expertise of educated egos responds more strongly to the frequency of contact between the ego and alter, which proxies for the strength of the tie. On the discussion of whether strong or weak ties are more helpful, our findings support Granovetter's later (1983, 1985) arguments, where he acknowledges the advantages of strong ties, rather than his earlier (1973) proposition that strong ties tend to carry redundant information. Perhaps the most remarkable finding, however, is that a knowledge advantage persists for Protestant producers till date, given that intensive efforts have been made by international development NGOs and the governmental extension service to spread expertise on apple widely since the late 1990s. Also the finding that Tolola village, the original insertion point of apple cultivation techniques, has retained a comparative advantage in know-how over adjacent villages, even when controlled for differences in years of experience with this crop, highlights the 'stickiness' of spatial proximity in addition to that of social proximity. This is not to say, however, that exclusion is necessarily a deliberate strategy, although the reported level of secrecy on apple cultivation suggests that strategic considerations play a certain part. Nor in fact can the exclusion be fully attributed to the ones with superior knowledge, i.e., Protestant producers. Interviews with key informants in the *Kale Heywet* church hint at self-exclusion on the part of Orthodox producers being uncomfortable tapping into the knowledge pool of the dominant religious group. However, our data do not allow verification of this assertion, nor estimation of its magnitude.

We are keenly aware that attribution of causality is tricky in our set-up and need not flow as uni-directionally as modeled in Figure 1. For example, we cannot rule out the possibility that well-connected farmers are systematically different characters than those who are poorly connected. For instance, it is conceivable that more entrepreneurial types tend to be more strongly embedded in networks, such that entrepreneurial attitudes rather than embeddedness in social networks drive our results. Entrepreneurial types may even feel more attracted to Protestantism in the first place, introducing unobserved selection bias. While acknowledging this possibility, it is reassuring that Freeman's case study in the Gamo highlands stresses the rather opportunistic motivation of converts to Protestantism. If indeed the avoidance of social sharing norms imposed by kin won them over, self-selection based on entrepreneurial spirit seems less likely to be a major confounding factor. Also, religious conversion in this narrative implies a deliberate breach with one's original social network, to be replaced with a new one, so that it is not the size of one's network that matters most, but its nature. This is not to say that religious affiliation and entrepreneurial attitudes are unrelated. It seems obvious that converts to Protestantism become more entrepreneurial over time through exposure to its gospel of 'personal liberation.' However, this is likely picked up in our model by the main effect of religion (being Protestant or not) rather than by the network variables.

Our findings hold several messages for policymakers and development agencies that work towards dissemination of new livelihood options in marginalized rural areas. First, it contains a warning not to be overoptimistic concerning the speed and breadth with which the new knowledge may spread across localities and across different social groups within these, even if the time span is relatively long. Intensifying formal training efforts, such as farmer field schools, is perhaps the most intuitive response in case knowledge dissemination falters, but the apple case in Chencha shows the limitations of such an approach. In tandem with technical interventions, it could prove useful to identify those groups who are socially ill-connected to the most knowledgeable individuals and consider 'soft' interventions to bring them closer to the knowledge source. Depending on the context, stimulating social interaction may be a complex

operation that requires substantial time and effort, but if exclusion through networks is observed to be important, it may be the more cost-effective and self-sustaining option eventually.

This policy implication is at odds with Mekonnen *et al*'s (2016) recommendation to concentrate effort and resources on building new professional networks rather than making organically grown ones (such as religious communities) more inclusive, as the latter would make poor conduits for the transmission of new agricultural techniques (row planting in their case) to start with. Our study rather highlights the effectiveness of a social network that has emerged along religious lines, despite the fact that agricultural knowledge diffusion was never its main purpose. We should acknowledge, however, that the case of apple in Chencha is somewhat special, as it was Protestant missionaries that brought in the new crop, establishing a clear association with a specific religious community from the outset. A final lesson concerns the result that different types of social network effects are effective for producers with different traits, which refers to the importance of visual inspection versus verbal contact for illiterate and literate producers, respectively. Social learning thus comes in different forms, requiring 'tailor-made' interventions when working with heterogeneous pools of producers.

Notes

1 Apple had in fact already been introduced in Chencha town, more specifically in the locality of Tolola, by Protestant missionaries in the 1950s, but little effort was put in diffusing the crop into the hinterlands (Girmay *et al*, 2014).

2 The term "Protestants" is meant to include Pentecostals as well as charismatic Evangelists. The main protagonist in the narrative on apple adoption is the *Kale Heywet* church, which is akin to Pentecostalism but became more charismatic over time (Eshete, 2013). The Chencha area also hosts other 'Protestant' churches; *Mulu Wengel* (aka Full Gospel Believers Church), which is described as Pentecostal, and *Mekane Yesus*, a charismatic outfit.

References

Alemu, S.H., van Kempen, L. and Ruben, R. (2017) Explaining technical efficiency and the variation in income of apple adoption in highland Ethiopia: The role of unequal endowments and knowledge asymmetries. *Journal of Agriculture and Rural Development in the Tropics and Subtropics* 118(1): 32–43.

Bandiera, O. and Rasul, I. (2006) Social networks and technology adoption in northern Mozambique. *The Economic Journal* 116(514): 869–902.

BenYishay, A. and Mobarak, A.M. (2014) Social Learning and Communication. NBER Working Paper No. 20139 (May), National Bureau of Economic Research.

Bernardi, L. (2011) A mixed-methods social networks study design for research on transnational families. *Journal of Marriage and Family* 73(4): 788–803.

Birkhaeuser, D., Evenson, R.E. and Feder, G. (1991) The economic impact of agricultural extension: A review. *Economic Development and Cultural Change* 39(3): 607–650.

Bramoullé, Y., Djebbari, H. and Fortin, B. (2009) Identification of peer effects through social networks. *Journal of Econometrics* 150(1): 41–55.

Conley, T.G. and Udry, C.R. (2010) Learning about a new technology: Pineapple in Ghana. *The American Economic Review* 100(1): 35–69.

Di Falco, S. and Bulte, E. (2011) A dark side of social capital? Kinship, consumption, and savings. *Journal of Development Studies* 47(8): 1128–1151.

Ellison, G. and Fudenberg, D. (1993) Rules of thumb for social learning. *Journal of Political Economy* 101(4): 612–643.

Eshete, T. (2013) The early charismatic movement in the Ethiopian Kale Heywet Church. *PentecoStudies* 12(2): 162–182.

Eshetu, F. and Mekonnen, E. (2016). Determinants of off farm income diversification and its effect on rural household poverty in Gamo Gofa Zone, Southern Ethiopia. *Journal of Development and Agricultural Economics* 8(10): 215–227.
Feder, G., Just, R.E. and Zilberman, D. (1985) Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change* 33(2): 255–298.
Feder, G., Murgai, R. and Quizon, J.B. (2004) The acquisition and diffusion of knowledge: The case of pest management training in farmer field schools, Indonesia. *Journal of Agricultural Economics* 55(2): 221–243.
Fetena, S., Shara, S., Anjulo, A., Gulie, G., Woldesenbet, F. and Yilma, B. (2014) Survey on apple production and variety identification in Chencha District of Gamo Gofa Zone, Southern Ethiopia. *Journal of Agriculture and Food Technology* 4(5): 7–15.
Freeman, D. (2012). Development and the rural entrepreneur: Pentecostals, NGOs and the market in the Gamo highlands, Ethiopia. In: D. Freeman (ed.) *Pentecostalism and Development: Churches, NGOs and Social Change in Africa*. Basingstoke: Palgrave Macmillan, pp. 159–180.
Friedkin, N.E. (1982) Information flow through strong and weak ties in intraorganizational social networks. *Social Networks* 3(4): 273–285.
Girmay, G., Menza, M., Mada, M. and Abebe, T. (2014) Empirical study on apple production, marketing and its contribution to household income in Chencha district of southern Ethiopia. *Scholarly Journal of Agricultural Science* 4(3): 166–175.
Granovetter, M. (1985). Economic action and social structure: The problem of embeddedness. *American Journal of Sociology*, 91(3): 481–510.
Granovetter, M. (1983). The strength of weak ties: A network theory revisited. *Sociological Theory* 1(1): 201–233.
Granovetter, M. (1973) The strength of weak ties. *American Journal of Sociology* 78(6): 1360–1380.
Grimm, M., Hartwig, R. and Lay, J. (forthcoming). Does forced solidarity hamper investment in small and micro enterprises? Forthcoming in *Journal of Comparative Economics*, doi:10.1016/j.jce.2016.07.002.
Helmers, C. and Patnam, M. (2014) Does the rotten child spoil his companion? Spatial peer effects among children in rural India. *Quantitative Economics* 5(1): 67–121.
Howells, J.R.L. (2002) Tacit knowledge, innovation and economic geography. *Urban Studies* 39(5–6): 871–884.
Hussain, S.S., Byerlee, D. and Heisey, P.W. (1994) Impacts of the training and visit extension system on farmers' knowledge and adoption of technology: Evidence from Pakistan. *Agricultural Economics* 10(1): 39–47.
Ipe, M. (2003) Knowledge sharing in organizations: A conceptual framework. *Human Resource Development Review* 2(4): 337–359.
Jakiela, P. and Ozier, O. (2016). Does Africa need a rotten kin theorem? Experimental evidence from village economies. *The Review of Economic Studies* 83(1): 231–268.
Krackhardt, D. (1992) The strength of strong ties: The importance of *philos* in organizations. In: N. Nohria and R.G. Eccles (eds.) *Networks and Organizations: Structure, Form, and Action*. Boston: Harvard Business School Press, pp. 216–239.
Krishnan, P. and Patnam, M. (2014) Neighbors and extension agents in Ethiopia: Who matters more for technology adoption? *American Journal of Agricultural Economics* 96(1): 308–327.
Lam, A. (2000) Tacit knowledge, organizational learning and societal institutions: An integrated framework. *Organization Studies* 21(3): 487–513.
Manski, C.F. (1993) Identification of endogenous social effects: The reflection problem. *The Review of Economic Studies* 60(3): 531–542.
Matuschke, I. and Qaim, M. (2009) The impact of social networks on hybrid seed adoption in India. *Agricultural Economics* 40(5): 493–505.
Mekonnen, D.A., Gerber, N. and Matz, J.A. (2016). Social Networks, Agricultural Innovations, and Farm Productivity in Ethiopia. ADB Working Paper No. 235 (April). African Development Bank.
Mohammad, A.H., Hamdeh, M.A. and Sabri, A.T. (2010) Developing a theoretical framework for knowledge acquisition. *European Journal of Scientific Research* 42(3): 453–463.
Platteau, J.P. (2009) Institutional obstacles to African economic development: State, ethnicity, and custom. *Journal of Economic Behavior & Organization* 71(3): 669–689.
Polanyi, M. (1966) The logic of tacit inference. *Philosophy* 41(155): 1–18.

Songsermsawas, T., Baylis, K., Chhatre, A. and Michelson, H. (2014). Can Peers Improve Agricultural Productivity? CESifo Working Paper No. 4958 (September), https://ssrn.com/abstract=2502809

Todo, Y., Mojo, D.Y., Matous, P. and Takahashi, R. (2011) Effects of geography and social networks on diffusion and adoption of agricultural technology: Evidence from rural Ethiopia. Paper presented in CSAE 25th Anniversary Conference on Economic Development in Africa, Center for the Study of African Economies, Oxford, UK, 20–22 March, 2011.

Topa, G. and Zenou, Y. (2014) Neighborhood and network effects. CEPR Discussion Paper No. DP10126 (September), https://ssrn.com/abstract=2501609.

Van den Broeck, K. and Dercon, S. (2011) Information flows and social externalities in a Tanzanian banana growing village. *Journal of Development Studies* 47(2): 231–252.

Appendix A

See Tables A1, A2, A3, A4, A5, A6, A7, A8 and A9 and Figures A1 and A2.

Table A1: Participation in pre- and post-adoption trainings, by provider

Training organization	*Pre-adoption training*			*Post-adoption training*			*Both*
	n	*%*	*Cum. %*	*n*	*%*	*Cum. %*	*n*
Cooperative	2	2	2	39	21	21	5
Extension	9	9	11	8	4	25	4
World Vision	32	34	45	40	22	47	9
Kale Heywet	49	52	97	86	47	94	18
Other	3	3	100	10	6	100	3
Total	95	100		183	100		39

Table A2: Level of education of the egos (producers)

Level of education	*n*	*%*	*Cum. %*
No formal education	63	16.58	16.58
Some primary education	109	28.68	45.26
Completed primary schooling	6	1.58	46.84
Some secondary education	38	10.00	56.84
Completed secondary education	58	15.26	72.11
Some college or university	30	7.89	80.00
Completed college or university	71	18.68	98.68
Graduate studies	5	1.32	100.00
Total	380	100	

Table A3: Religious affiliation of egos (producers)

Religion of ego	*n*	*%*	*Cum. %*
Orthodox Christian	77	20.26	20.26
Protestant (Pentecostal)	300	78.95	99.21
Muslim	1	0.26	99.47
Other Religion	2	0.53	100.00
Total	380	100	

Table A4: The type of relation between ego and alters

Relation of ego with tie	*Tie 1*		*Tie 2*		*Tie 3*	
	n	%	*n*	%	*n*	%
Friend	201	57.6	179	62.6	169	67.3
Kin	71	20.3	37	12.9	29	11.5
Family	18	5.2	23	8.1	20	8.0
Other	59	16.9	47	16.4	33	13.2
Total	349	100	286	100	251	100

Table A5: Regression of knowledge on other controls and ego characteristics only

Variables	*(1)*	*(2)*	*(3)*	*(4)*
Education of ego (in years)	0.122	0.129	0.060	0.010
	(0.019)***	(0.018)***	(0.020)***	(0.021)
Pre-adoption training	0.538	0.457	0.354	0.215
(1 = yes; 0 = no)	(0.193)***	(0.190)**	(0.203)*	(0.200)
Post-adoption training	0.866	0.805	0.816	0.834
(1 = yes; 0 = no)	(0.180)***	(0.177)***	(0.166)***	(0.161)***
Apple cultivation experience	0.071	0.067	0.063	0.081
(in years)	(0.016)***	(0.016)***	(0.015)***	(0.015)***
Farms visited last season	0.017	0.016	0.013	0.012
	(0.003)***	(0.003)***	(0.003)***	(0.003)***
Religion (1 = Protestant;		0.884	0.941	0.736
0 = other)		(0.203)***	(0.199)***	(0.195)***
Doko Shaye *kebele*†			−0.663	−0.551
			(0.254)***	(0.249)**
Doko Losha *kebele*†			−1.750	−1.710
			(0.231)***	(0.228)***
Chencha town†			−0.012	−0.005
			(0.237)	(0.231)
Asset (livestock, equipment,				0.265
house)				(0.068)***
Welfare (house, water, light)				−0.135
				(0.063)**
Gender of household head				−0.309
(1 = female)				(0.238)
Age of household head				−0.027
				(0.006)***
Constant	−2.414	−3.068	−1.834	0.063
	(0.223)***	(0.264)***	(0.337)***	(0.561)
F statistic	38.86	37.12	37.05	30.32
Adjusted *R*-squared	0.33	0.36	0.46	0.50
Number of observations	380	380	380	380

Note: The figures in parenthesis represent the robust standard error. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; † Reference category: Tolola.

Table A6: Regression of knowledge on "average" alter characteristics and controls

Variables	*Knowledge*	*Knowledge*	*Knowledge*	*Knowledge*
Education of ego in years	0.181	0.151	0.106	0.114
	(0.036)***	(0.033)***	(0.035)***	(0.035)***
Education of alters averaged	0.153	0.062	−0.002	0.025
	(0.039)***	(0.037)	(0.041)	(0.042)
Religion (1 = Protestant; 0 = other)	1.002	0.759	0.829	0.845
	(0.313)***	(0.281)***	(0.281)***	(0.278)***
Religion alter, # of protestants	−0.031	−0.056	−0.044	0.010
	(0.180)	(0.162)	(0.160)	(0.161)
Age of ego	−0.019	−0.027	−0.031	−0.029
	(0.010)*	(0.010)***	(0.009)***	(0.009)***
Age of alters, average age	0.012	−0.005	0.014	0.017
	(0.012)	(0.011)	(0.012)	(0.012)
Gender of ego (1 = female)	0.453	0.284	0.076	0.169
	(0.490)	(0.438)	(0.432)	(0.429)
Share of female connections	0.011	0.016	0.009	0.004
	(0.017)	(0.015)	(0.015)	(0.015)
Experience		0.070	0.070	0.069
		(0.021)***	(0.021)***	(0.021)***
Pre-adoption training		0.373	0.403	0.435
		(0.321)	(0.316)	(0.313)
Post-adoption training (1 = yes; 0 = no)		1.141	1.121	1.089
		(0.229)***	(0.224)***	(0.222)***
Farms visited last season		0.011	0.010	0.010
		(0.003)***	(0.003)***	(0.003)***
Dummy for Doko Shaye kebele			−0.098	0.247
			(0.943)	(0.944)
Dummy for Doko Losha kebele			−1.289	−1.078
			(0.371)***	(0.377)***
Dummy for Chencha town			−0.115	−0.061
			(0.279)	(0.277)
Frequency of contact per month				0.030
				(0.013)**
Constant	−3.829	−2.697	−1.663	−2.910
	(0.997)***	(0.906)***	(0.956)*	(1.077)***
F statistic	15.07	17.81	15.97	15.70
Adjusted *R*-squared	0.33	0.47	0.50	0.51
Number of observations	227	227	227	226

Note: The figures in parenthesis represent the robust standard error. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A7: Regression of knowledge on interaction terms and other controls

Variables	*Knowledge*	*Knowledge*	*Knowledge*	*Knowledge*
Education of ego in years	0.113	0.117	0.121	0.129
	(0.035)***	(0.035)***	(0.035)***	(0.035)***
Education of alters averaged	0.023	0.034	0.037	0.041
	(0.042)	(0.043)	(0.043)	(0.043)
Religion alter, # of protestants	−0.029	0.021	−0.024	−0.087
	(0.164)	(0.165)	(0.162)	(0.153)
Age of ego	−0.030	−0.031	−0.029	−0.026
	(0.009)***	(0.009)***	(0.009)***	(0.009)***
Age of alters, average age	0.018	0.022	0.023	0.024
	(0.012)	(0.012)*	(0.012)*	(0.012)**

Table A7: *continued*

Variables	*Knowledge*	*Knowledge*	*Knowledge*	*Knowledge*
Gender of ego (1 = female)	0.150	0.198	0.195	0.196
	(0.434)	(0.437)	(0.438)	(0.438)
Share of female connections	0.005	0.004	0.005	0.003
	(0.015)	(0.015)	(0.015)	(0.015)
Farms visited last season	0.010	0.011	0.011	0.011
	(0.003)***	(0.003)***	(0.003)***	(0.003)***
Dummy for Doko Shaye	0.206	0.306	0.313	0.355
kebele	(0.952)	(0.963)	(0.965)	(0.965)
Dummy for Doko Losha	−1.108	−1.071	−1.103	−1.102
kebele	(0.380)***	(0.384)***	(0.384)***	(0.385)***
Dummy for Chencha town	−0.085	−0.109	−0.151	−0.123
	(0.279)	(0.283)	(0.281)	(0.281)
Frequency of contact per	0.030	0.035	0.036	0.036
month	(0.013)**	(0.013)***	(0.013)***	(0.013)***
Experience * Religion	0.051	0.032	0.077	0.060
	(0.043)	(0.043)	(0.024)***	(0.020)***
Pre-adoption training *	−0.229	0.350	0.331	0.276
Religion	(0.795)	(0.354)	(0.354)	(0.351)
Post-adoption training *	0.051	1.064	1.056	0.990
Religion	(0.486)	(0.264)***	(0.265)***	(0.259)***
Religion (1 = Protestant;	0.330	−0.036	−0.469	
0 = other)	(0.534)	(0.519)	(0.394)	
Experience	0.031	0.048		
	(0.038)	(0.038)		
Pre-adoption training	0.599			
(1 = yes; 0 = no)	(0.718)			
Post-adoption training	1.041			
(1 = yes; 0 = no)	(0.416)**			
Constant	−2.385	−2.498	−2.099	−2.414
	(1.161)**	(1.175)**	(1.134)*	(1.104)**
F statistic	13.23	13.97	14.69	15.55
Adjusted *R*-squared	0.51	0.49	0.49	0.49
Number of observations	226	226	226	226

Table A8: Principal components/Correlation for the knowledge categories

Variable	*Eigenvalues*	*Difference*	*Proportion*	*Cumulative*
Comp1	3.97	3.42	0.66	0.66
Comp2	0.54	0.06	0.09	0.75
Comp3	0.48	0.05	0.08	0.83
Comp4	0.44	0.09	0.07	0.90
Comp5	0.34	0.12	0.05	0.96
Comp6	0.22	–	0.04	1.00
Tests				
Cronbach's Alpha: Average interim covariance = 0.77 and Scale reliability coefficient = 0.895.				
Observations	380			

Table A9: Eigen vectors of the principal components for knowledge categories

Variable	*Comp1*	*Comp2*	*Comp3*	*Comp4*	*Comp5*	*Comp6*	*KMO test*
Var1	0.43	−0.26	−0.44	0.04	0.10	−0.73	0.84
Var2	0.42	−0.52	−0.36	0.03	−0.01	0.64	0.84
Var3	0.40	0.27	0.19	0.78	−0.35	0.02	0.92
Var4	0.39	−0.22	0.71	−0.06	0.53	−0.03	0.91
Var5	0.41	0.07	0.23	−0.58	−0.65	−0.05	0.90
Var6	0.38	0.73	−0.29	−0.21	0.39	0.19	0.89

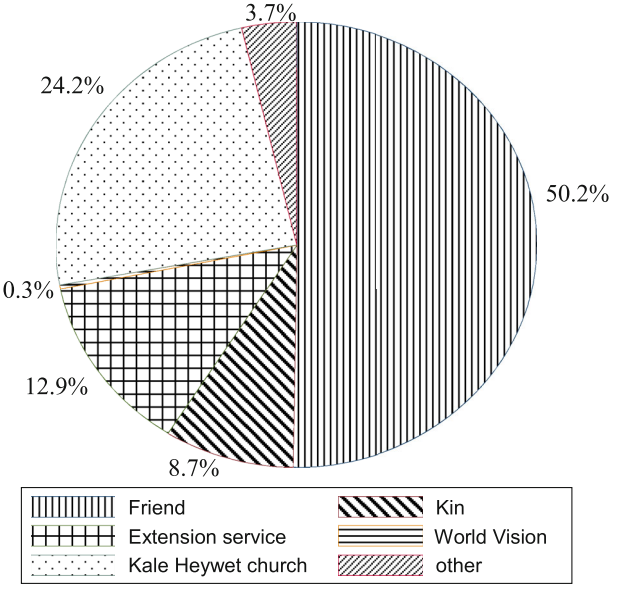

Figure A1: Most important source of information on apple cultivation at time of interview (2013).

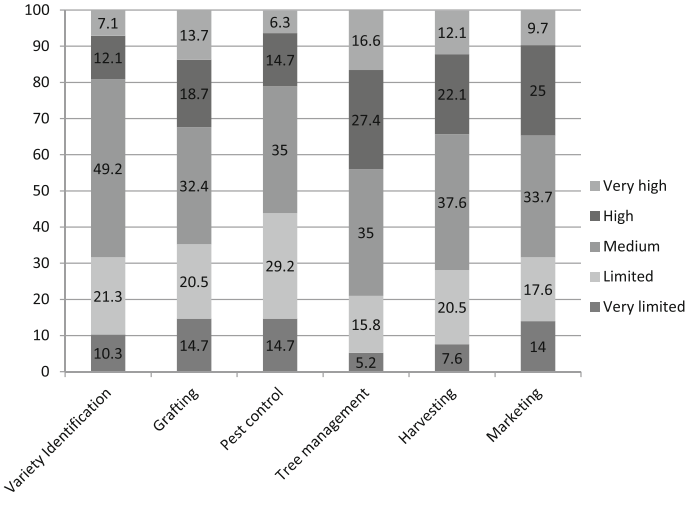

Figure A2: Cumulative distribution of knowledge levels per task.