family (we restricted this to maternal, infant, or child mortalities at the time of pregnancy), knowledge (tested via a 10-question quiz about maternal, infant, and child health), and need for medical care (coded as a 1 if the participant became pregnant). We also controlled for prior experience with modern medical care (yes or no) because women who have used modern medical care could be expected to use it again compared to those who have not used it.

Given that kiosk use and seeking modern medical care are skewed, we performed data transformations on these two variables. Among the three commonly used transformation methods, i.e., square root, log, and inverse, we used log transformation because this method is suitable when there are extreme values (Osborne 2002). In addition, square root transformation is not suitable for continuous variables, with values ranging between 0 and 1 and inverse transformation has the effect of reversing the order of scores (Osborne 2002).

RESULTS

We used UCINET 6.29 (Borgatti et al. 2002) to calculate the various network centralities. Given that variables were measured at different levels—i.e., advice network centralities, time (i.e., year), kiosk use, seeking modern medical care, and maternal mortality at the individual level; and lead user centralities at the village level—hierarchical linear modeling (HLM) was used to test our model because it takes into account the non-independence of observations and adjusts the degrees of freedom to account for relationships of individuals nested within villages (see Bryk and Raudenbush 1992; Singer and Willett 2003). Specifically, we used HLM 6.29 (Bryk and Raudenbush 1992) to test the model. A prerequisite for running HLM models is a significantly higher level of unit variance in the outcome measure (Hofmann 1997; Hofmann et al. 2000), which was found to be true. The NULL two-level model with no predictors showed that significant variance was explained between villages. The statistics, i.e., r_{wg}, ICC(1) and

ICC(2), that assess agreement among individuals at a lower level are not necessary in this context because lead user centralities are conceptualized as a global property at the village level (Klein and Kozlowski 2000).

Table 1 shows the descriptive statistics and correlations. The pattern of correlations between the different centralities and seeking modern medical care and maternal mortality was in the expected direction, thus lending preliminary support to our hypotheses. Several of the control variables were also correlated with the key dependent variables. As shown in Table 2, the maternal mortality rates of the intervention group were lower than those of the control group after the kiosks were implemented and used for some time, indicating the effectiveness of the kiosks in assisting women seeking medical care. It should be noted that these are overall statistics for the villages we studied and are not necessarily restricted only to those women who we followed during the study.

Our data indicated that less than 20 women in each village used a kiosk, especially in the first year, thus lending face validity to a focus on one lead user. The results of primary model testing are shown in Table 3. The main effects model that included strong tie and weak tie centralities at both the individual and village levels explained 31% of the variance in kiosk use (model 2), an increase of 12% of the variance compared to the model with control variables only (model 1). We found that strong tie centralities at both levels had negative effects on kiosk use, whereas weak tie centralities had positive effects on kiosk use. Thus, H1a, H1b, H2a, and H2b were supported. The main effects model that included kiosk use explained 38% of the variance in seeking modern medical care (model 2), an increase of 10% of the variance compared to the model with control variables only (model 1). We found that kiosk use had a positive effect on seeking modern medical care. Therefore, H3 was supported. In predicting maternal mortality, the

main effects model that included kiosk use and seeking modern medical care explained 37% of the variance in maternal mortality (model 2), an increase of 11% of the variance compared to the model with control variables only (model 1). We found that kiosk use and seeking modern medical care had negative effects on maternal mortality, thus supporting H4 and H5. The addition of kiosk use and seeking modern medical care to the control variables only model resulted in a significant increase in the variance explained in maternal mortality.

The model with the interaction effects of network variables and time on kiosk use explained 43% of the variance in kiosk use (model 3), an increase of 12% of the variance compared to the model with main effects only (model 2). We examined the results with increasing time (i.e., year). We found that the effects of strong and weak tie centralities on kiosk use varied across time in that the effects of weak tie centralities became stronger with time, whereas the effects of strong tie centralities became weaker over time. Thus, H6a, H6b, and H6d were supported. Given that the moderating effect was not significant for strong tie centrality at the village level, H6c was not supported. The model with the interaction effect of kiosk use and time on seeking modern medical care explained 46% of the variance in seeking modern medical care (model 3), an increase of 8% of the variance compared to the model with main effects only (model 2). We found the positive effect of kiosk use on seeking modern medical care became stronger over time, thus supporting H7. The model with the interaction effects of kiosk use and time on maternal mortality and seeking modern medical care and time on maternal mortality explained 48% of the variance in maternal mortality (model 3), an increase of 11% of the variance compared to the model with the main effects only (model 2). We found the negative effect of kiosk use on maternal mortality became stronger over time, thus supporting H8. We also found the negative effect of seeking modern medical care on maternal mortality became

stronger over time, thus supporting H9. As a robustness check, we conducted additional analysis to fortify the pattern of findings (Appendix B). Although not directly related to the hypotheses, we examined whether the effects of social network ties on seeking modern medical care and maternal mortality were mediated by kiosk use (detailed results not reported here). Interestingly, we found that kiosk use partially mediated the effects of strong tie and weak tie centralities on seeking modern medical care and maternal mortality.

Table 1. Descriptive Statistics and Correlations

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Village population	1,540.22	78.51																
2. Lead user strong tie centrality	42.28	7.73	.13*															
3. Lead user weak tie centrality	31.80	6.90	.14**	-.21***														
4. Time (year)	NA	NA	.16**	.14*	.16**													
5. Age	27.12	13.21	.07	.15**	.17**	.16**												
6. Marital status (1: married)	NA	NA	.05	.13*	.14*	.09	.05											
7. Number of children	3.81	1.01	.19***	.19**	-.08	.19**	.23***	.22***										
8. Education	NA	NA	.03	-.12*	.15**	.05	-.10*	-.12*	-.19***									
9. Mortalities in family	1.07	0.44	.15**	.20***	-.21***	.11*	.14**	.08	-.15**	-.21***								
10. Knowledge (10-point scale)	4.20	2.89	.03	-.13*	.15**	.17**	-.17**	-.13*	-.20***	.28***	.13*							
11. Need (pregnancy)	0.20	0.11	.15**	.07	.10*	.17**	.13*	.35***	.20***	-.15**	.16**	-.20***						
12. Exp with modern medical care	0.13	0.10	.17**	-.23***	.25***	.10*	-.20***	-.17**	.03	.31***	-.23***	.38***	-.14*					
13. Strong tie centrality	35.59	10.25	.20***	.09	.07	.10*	.24***	.13*	.19***	-.21***	.23***	-.21***	.20***	-.20***				
14. Weak tie centrality	29.16	11.20	.23***	.13**	.14**	.08	-.19***	-.14**	-.24***	-.28***	-.25***	.24***	-.13*	.24***	-.20***			
15. Kiosk use	1.16	5.36	.14*	-.28***	.31***	.29***	-.15**	-.17**	.13*	.15**	.28***	.16**	.19**	.29***	-.39***	.38***		
16. Seeking modern medical care	1.06	0.55	.19**	-.30***	.34***	.28***	.28***	.07	.24***	.24***	.16**	.34***	.29***	.38***	-.44***	.44***	.28***	
17. Maternal mortality	0.10	0.04	.12*	.28***	-.31***	-.17**	-.10*	.12*	.12*	-.15**	.14**	-.26***	.23***	-.33***	-.34***	.37***	-.24***	-.28***

* p < .05; ** p < .01; *** p < .001.

Table 2. Mortality Rates

	Maternal Mortality	
Year	**Control group**	**Intervention group**
2002	73.1	73.5
2003	70.3	70.8
2004 (intervention)	68.4	68.5
2005	66.2	65.1
2006	64.1	61.8
2007	61.8	56.4
2008	59.4	52.2
2009	57.3	49.1
2010	55.2	47.4
2011	52.8	46.1

* Coded as the number per 1,000 live births (still-born data accuracy was low, thus excluded).

Table 3. Results of Model Testing

	Kiosk Use						Seeking Modern Medical Care						Maternal Mortality					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
R^2	.19		.31		.43		.28		.38		.46		.26		.37		.48	
ΔR^2			.12***		.12***				.10***		.08**				.11***		.11***	
Level 2																		
Control variable:																		
Village population	.11*	.06	.05	.09	.03	.13	-.14*	.04	-.12**	.08	-.05	.17	.24***	.06	.20***	.04	.14*	.05
Predictors:																		
Lead user strong tie centrality (LUSTC)			-.19**	.04	-.13*	.05												
Lead user weak tie centrality (LUWTC)			.16**	.05	.12*	.06												
Cross-level interactions:																		
LUSTC X Time					.04	.15												
LUWTC X Time					.26***	.04												
Level 1																		
Control variables:																		
Age	-.12*	.05	.11*	.04	.06	.16	.19***	.04	.17**	.06	.11*	.05	.15**	.06	.13*	.05	.11*	.04
Marital status	-.13*	.05	.05	.19	.03	.20	-.11*	.05	-.10*	.17	.06	.14	-.12*	.07	-.12*	.07	.10*	.10
# of children	.12*	.03	.06	.18	.04	.21	.05	.16	.05	.15	.02	.14	.04	.15	.04	.14	.02	.13
Education	.05	.14	.03	.17	.02	.16	.06	.19	.06	.13	.02	.11	-.07	.13	.04	.14	.02	.12
Mortalities in family	.19**	.04	.15**	.04	.11*	.04	.17**	.04	.16**	.06	.10*	.07	.13*	.04	.13*	.03	.12*	.05
Knowledge	.08	.10	.05	.18	.03	.17	.22***	.04	.19***	.05	.13*	.06	-.17**	.04	-.14**	.05	-.14*	.04
Need (pregnancy)	.07	.12	.04	.22	.03	.19	.30***	.05	.24***	.04	.16**	.04	.28***	.05	.25***	.03	.21***	.03
Exp with modern medical care	.24***	.06	.18**	.06	.14**	.03	.19***	.04	.16**	.05	.09	.08	-.19***	.04	-.17**	.04	.15**	.02
Predictors:																		
Strong tie centrality (STC)			-.24***	.04	-.17**	.04												
Weak tie centrality (WTC)			.19**	.05	.16**	.04												
Time (year)					.15**	.04					.18**	.04					-.13*	.02
STC X Time					-.13*	.05												
WTC X Time					.30***	.04												
ICT kiosk use (KU)									.38***	.04	.25***	.04			-.24***	.03	-.16**	.03
Seeking modern medical care (SMMC)															-.42***	.04	-.29***	.05
Interactions:																		
KU X Time											.28***	.05					-.17**	.05
SMMC X Time																	-.30***	.04

* p < .05; ** p < .01; *** p < .001.

DISCUSSION

We developed a two-level model to understand the role of social ties of women in rural India in influencing their use of a new kiosk, and the effects of kiosk use on seeking modern medical care and maternal mortality, and seeking modern medical care on maternal mortality. Our model was largely supported and the network variables at different levels played an important role in explaining kiosk use, i.e., our model explained 31% of the variance in kiosk use, 38% in seeking modern medical care, and 37% in maternal mortality. As predicted, weak tie centralities had positive effects on kiosk use, whereas strong tie centralities had negative effects on kiosk use. In addition, as predicted, kiosk use had a positive effect on seeking modern medical care and a negative effect on maternal mortality, and seeking modern medical care had a negative effect on maternal mortality. Finally, we found that the effects of various predictors change over time. By incorporating time, our model explained 43% of the variance in kiosk use, 46% in seeking modern medical care, and 48% in maternal mortality.

Theoretical Contributions and Implications

We make important contributions to research on ICT implementations, ICT4D, and e-government. Our work goes beyond prior IS research that focuses on techno-centric outcomes, especially technology use, by examining the consequences of an IS implementation (see Venkatesh et al. 2016c). Two important outcomes, i.e., seeking modern medical care and maternal mortality, were examined in the relatively understudied context of an ICT4D intervention in a rural area of a developing country. By examining consequences of such an ICT4D intervention, we develop a more holistic understanding of the nomological network around technology use, thus extending the theory bases used to understand technology adoption, use and success (e.g., Chatterjee et al. 2009; Sarker et al. 2010; Venkatesh et al. 2003, 2016c). In

addition, our work leverages social networks research, particularly social contagion theory, to better understand ICT implementation outcomes. We thus gain a better understanding of the role of social influence in affecting ICT diffusion (e.g., Sarker et al. 2011a, 2011b) by overcoming the limitations of focusing only on technology factors. Specifically, the fact that network effects can cut both ways—positively and negatively—is potentially worrisome and its presence in other contexts, including organizational settings, should be investigated.

Our model can be adapted to other domains that are important to advancing the human condition. Whereas this paper seeks to address the problem of information asymmetry in medical care for women in developing countries, our model sheds light on how to resolve information asymmetry in other domains. For example, it will be interesting to examine the roles of ICT and social networks in transmitting social influence and disseminating the best practices in agriculture, fishing, and environmental protection. In addition to addressing the problem of information asymmetry, social networks and ICT are expected to advance the human condition in other domains, such as improving quality of education by enabling speedy access to diverse knowledge or strengthening social bonding by extending offline communication to online media (see also Zhang and Venkatesh 2013).

Our work contributes to research on ICT4D. Whereas most prior research examines the ICT4D initiatives in developed countries (e.g., Agarwal et al. 2009; Hsieh et al. 2008), there has been a call for research on ICT4D in developing countries given that the most severe forms of the digital divide exist in developing countries (UNDP 2004). By developing and testing a model of women's health outcomes of an ICT4D initiative in rural India, our work makes a contribution to this literature base. Research that seeks to understand the drivers of the success of such initiatives is limited. By conducting a longitudinal study examining the impacts of an ICT4D

initiative, our work complements prior research on this topic (e.g., Keniston and Kumar 2004). Also, prior research has mainly focused on understanding the digital divide at either a micro- or macro-level and this work extends prior research by developing a multi-level model that incorporates cross-level network effects to gain a better understanding of healthcare outcomes. Further, as we articulated at the outset, it is important to understand how ICTs can impact key outcomes. The type of outcomes and the impacts studied in this work place ICT in a key role in helping to save lives.

This paper contributes to the literature on strategic uses of ICTs that underscores the key role of "champions," i.e., managers who actively promote their personal vision for using ICTs and overcoming hurdles to successful implementations of ICTs (e.g., Beath 1991; Liang et al. 2007). Although lead users defined in this paper are not the same as champions noted in prior literature, they are similar in that both emphasize the use of personal characteristics, e.g., charisma, inspiration and stimulation, to influence the success of ICT implementations. However, we suggest that it is not sufficient to only examine personal characteristics to understand the role of lead users in influencing implementations of ICTs. The broader social context, e.g., advice networks, and the underlying mechanisms of social contagion theory that explain opinions of salient or relevant others needs to be incorporated to understand the influence of lead users. We found that lead users who have high strong tie centrality are likely to work against the ICT4D initiative. This suggests that we should also examine the role of champions in other contexts to gain a better understanding of their influence on ICT implementations.

Our results underscore the importance of incorporating time in theory development. This work helps us to develop a better understanding of the effects of networks on kiosk use, the effect of kiosk use on seeking modern medical care, and the effect of seeking modern medical

care on maternal mortality. Specifically, we found that it takes time for the positive effects to build up—i.e., the effects of weak tie centralities on kiosk use, the effect of kiosk use on seeking modern medical care, and the effect of seeking modern medical care on maternal mortality become stronger over time. This work indicates the theoretical formulation and methodological approaches will be different when time is considered. Specifically, theorizing about and empirically examining time enriched our understanding of the phenomenon. Future research should also translate time into specific temporal concepts, such as timing and sequencing, to more richly treat and validate the effects of time in the context of ICT implementations, such as this one and even organizational implementations (see Venkatesh et al. 2006).

Our findings also have implications for social networks research. Whereas prior social networks research has discussed the general implications of strong ties—e.g., trust and reciprocity (Granovetter 1973; Krackhardt 1992) and transfer of complex knowledge (e.g., Reagans and McEvily 2003)—and weak ties—e.g., access to diverse and novel information (e.g., Baer 2010; Perry-Smith 2006; Zhou et al. 2009)—there is still an inadequate understanding of when strong ties or weak ties will have a positive effect on outcomes of interest. For example, the question of whether strong ties or weak ties contribute to innovation has not been adequately understood. Prior research indicates that the incorporation of contextual factors will shed light on our understanding of phenomena in general (e.g., Johns 2006; Zhou et al. 2009)—in this vein, this work extends prior research by incorporating important contextual mechanisms and arguments to better understand the effects of strong ties and weak ties on women's behaviors and outcomes in rural India. In addition, the incorporation of social contagion theory sheds light on our understanding of the differences between strong ties and weak ties in transmitting social influence that is critical for the success of the ICT4D intervention. Moreover, the cross-level

theorizing of network factors helps us develop a more holistic understanding of the phenomenon. The conceptualization of the lead user at the village level helps us gain a better understanding of how networks affect lower-level outcomes. Our work thus indicates the importance of conceptualizing key roles, such as lead user, as a higher-level network construct, in understanding outcomes of interest. Such effects could also be examined in other research using social networks.

Limitations and Future Research

First, whereas we conducted a longitudinal study (about 7 years) to enhance the robustness of our results, we did not study network change. Both a lead user's and women's networks could change over time. We thus suggest examining network change and its impacts on change in kiosk use in future research using approaches such as latent growth modeling (see Bala and Venkatesh 2013). Second, we argue that acculturation and prevalent social cultural norms play an important role in affecting women's attitudes toward using technologies to obtain information about seeking modern medical care, but we have not actually measured these mechanisms. Future research can empirically validate the impacts of these two mechanisms. Third, our work indicates the critical role of a lead user in affecting women's views toward using the kiosk and the information they provide about medical care. Future research should account for differences across lead users (e.g., personality, espoused culture) to rule out alternative explanations based on individual differences. In addition, given that our study identified only one woman as a lead user for each village, the results could be biased if the lead user cannot represent the influence on the majority, i.e., women who used the kiosks on a frequent basis in a village. This concern is likely to be trivial in our study due to the low base rate of kiosk use in the villages. However, future research could include more lead users to enrich our understanding

of their role in this context. In addition, future research could include men in the network, and investigate their influence both as lead users and in cross-gender communication. Fourth, some of our measures have limitations. We defined a lead user as the one woman who began using the ICT the earliest and did so on a frequent basis. Such a definition may be problematic when the following scenarios occur: (a) if one woman used the kiosk earlier than another woman but the latter used the kiosk more frequently; and (b) if the lead user also has the largest number of strong ties, the largest number of weak ties, or the least of either category. With respect to the measure of maternal mortality, we have not distinguished among different causes of death. Some women might die during or immediately after pregnancy due to reasons unrelated to being unwilling to seek modern medical care, such as natural catastrophe, health issues in tropical countries (e.g., snake bite), car accidents or suicide. We found the number of mothers who died because of these other reasons to be small. However, future research could classify mortality in a more nuanced fashion. Finally, our work, though extensive, was a quantitative study that has known limitations (see Venkatesh et al. 2013; Venkatesh et al. 2016a). Conducting a qualitative study through a combination of unstructured interviews and observations and/or using a mixed methods approach may afford us a more complete understanding of the phenomenon (Venkatesh et al. 2016a).

Practical Implications

Successful deployments of ICT4D interventions in developing countries are rare. In rural India, there are significant obstacles to using ICTs to promote modern medical care for women. We found evidence that using ICTs to obtain information about modern medical care is more likely to be reinforced via strong ties. Therefore, it is crucial to develop ways to overcome the negative effects of strong ties. One possible approach to help reduce negative acculturation is to

create opportunities for women in villages to use the kiosks to obtain information about modern medical care that are positive experiences. When women experience the benefits of using ICTs to obtain information about modern medical care, they are more likely to challenge traditional medical practices. The more women use ICTs, the more likely they will experience the benefits of using ICTs to obtain information about medical care. Such positive experiences are likely to be transmitted via the network to accelerate the diffusion of ICTs. In order to facilitate use of ICTs, governments can allocate more resources to help women to learn and use ICTs—but, in the case of remote Indian villages, this starts with basic literacy and ICTs could be used to achieve this purpose as well. Governments can also promote the benefits of using ICTs, such as asking women who have benefited from using ICTs to obtain information about modern medical care and using modern medical care, to share their experience and stories in meetings in villages in which they live and also neighboring villages. The local village government (i.e., Panchayat) meetings in villages in India provide an excellent setting for such information sharing as such meetings tend to be more sociopolitical rather than being purely political.

Our work found that the effects of acculturation are likely to diminish and women feel less social pressure to conform when they were connected via weak ties, especially over time. Weak ties were more likely to disseminate factual information about how ICTs can be leveraged to obtain information about modern medical care and about modern medical care itself. Thus, it will be useful to foster more weak ties. One approach to create more weak ties is to hold social events among villagers, many of whom may not know each other, especially as the villages targeted with such interventions become larger. People are likely to talk to others during such events and they may start contacting each other after the events occasionally, thus forming weak ties. Using these weak ties, the lead users can share information about modern medical care with

other women. Gradually, the negative views that prevail about the new kiosk and modern medical care will then attenuate. A further step could be to carefully identify a woman with high weak tie centrality and recruit her to be the lead user. Thus, weak ties may be employed as a solution to the problems caused by strong ties.

CONCLUSIONS

This work drew on social networks theory in general and social contagion theory in particular to develop a multi-level model to predict kiosk use, seeking modern medical care, and maternal mortality. In the context of an ICT4D initiative designed to assist women in rural India to obtain maternal health care, our work found that an advice network played a dual role in affecting the objectives of the ICT4D initiative. The duality of the network effects, such that both positive and negative effects occur, is at the heart of our understanding of the phenomenon. Our work not only provides an important explanation for why some ICT4D initiatives in rural parts of developing countries fail, but also identifies potential solutions to address the problem. Finally, given that our work was conducted in rural India, the implications for deploying such interventions in India substantial.

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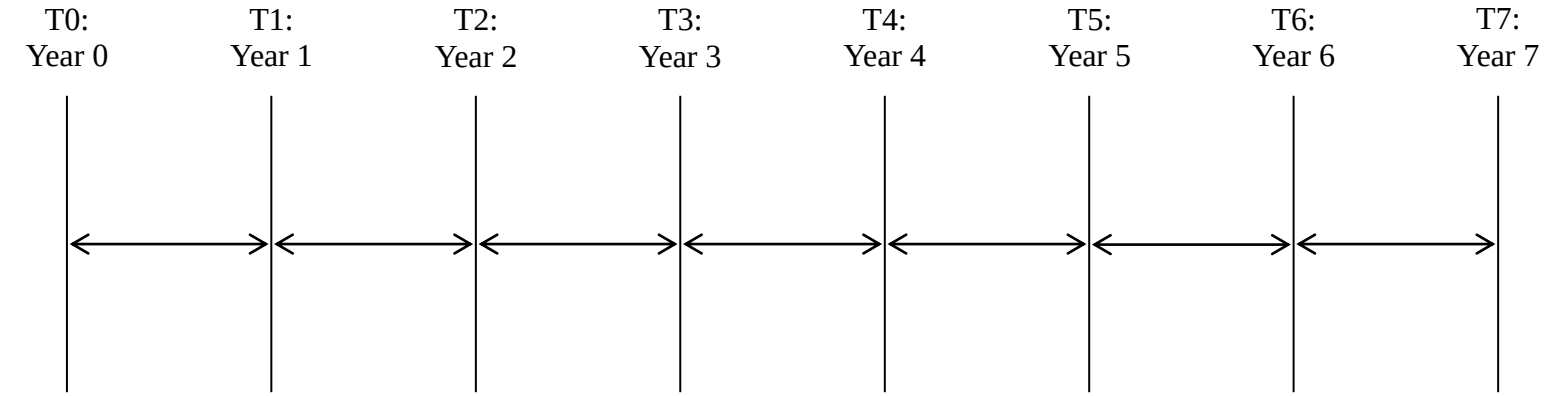
Appendix A. Data Collection Timeline



First two months between T0 and T1: Kiosk impln. and training

Initial survey on advice networks, demographics and other control variables	Collection of kiosk use, advice networks, seeking modern medical care, mortality data, demographics and other control variables	Collection of kiosk use, advice networks, seeking modern medical care, mortality data, demographics and other control variables	Collection of kiosk use, advice networks, seeking modern medical care, mortality data, demographics and other control variables	Collection of kiosk use, advice networks, seeking modern medical care, mortality data, demographics and other control variables	Collection of kiosk use, advice networks, seeking modern medical care, mortality data, demographics and other control variables	Collection of kiosk use, advice networks, seeking modern medical care, mortality data, demographics and other control variables	Collection of kiosk use, advice networks, seeking modern medical care, mortality data, demographics and other control variables

Appendix B: Robustness Checks

Measurement of Seeking Modern Medical Care

One of the challenges with data such as ours is the low base rate of pregnancies, kiosk use, seeking modern medical care, and mortalities that results in a skewed distribution. Although we can seek analytical remedies, i.e., data transformation (here, log transformation), to address skewed or non-normal data (Fujioka and Maesono 2000; Osborne 2002), to address this issue, we wanted to conduct additional analysis with other data that would help fortify the pattern of findings. To this end, we examined women seeking modern medical care in general, regardless of pregnancy. Such an examination would provide insights into whether or not modern medical care could lead to positive impact. Such an analysis also has noise as the need for medical care is often tied to age and overall health, and for the latter, we had no way to measure or control. We see this analysis as one that can be viewed in conjunction with our other analyses to provide evidence of robustness. The results of these additional analyses (not reported in detail here) were similar to those reported in Table 3. Specifically, we observed negative effects of strong tie centralities on kiosk use and seeking modern medical care and the weakening of these effects over time. Likewise, we observed positive effects of weak tie centralities on kiosk use and seeking modern medical care and the strengthening of these effects over time. We also observed negative effects of kiosk use and seeking modern medical care on mortalities and the strengthening of these effects over time.