Supplement

This Supplement provides a detailed review of the Partners In Health – Rwanda Ministry of Health intervention under evaluation, and additional technical information about how data were collected and analyzed.

1. PIH-RMOH intervention

Table s1. Three levels of health care delivery in PIH-RMOH intervention in Kirehe/S. Kayonza

District Hospitals (1 in Kirehe and 1 in S. Kayonza)
Full renovation of abandoned hospital for 95-bed facility in S. Kayonza. Constructed 140-bed district hospital in Kirehe. Each included: electricity, water and sanitation, emergency room, operating room, laboratory, kitchen, and wards for obstetrics, internal medicine, pediatrics, post-surgery, oncology, and tuberculosis. Services included blood transfusions, radiology, ultrasound, electrocardiogram, outpatient specialty consultations (dentistry, high-risk pregnancies, orthopedics, mental health), and social work. Both established an ambulance network, electronic medical records (EMRs), strengthened supply chain management, and forecasting for drugs and consumables. Hospitals were staffed to GoR norms: 12 doctors, 60+ nurses, 7 laboratory technicians among others;[1,2] they received trainings in obstetrics, pediatrics, internal medicine, infectious disease, malnutrition, organizational management, and mentorship from specialty doctors (often foreign trained). PIH supported insurance (*mutuelles*) for indigents, and covered point-of-service fees for any patients that could not pay. Staff received additional incentives through performance-based financing (PBF).
Health Centers (12 in Kirehe and 8 in S. Kayonza)
Six health centers (4 in Kirehe, 2 in S. Kayonza) received infrastructure upgrades that included: electricity, internet, water and sanitation, furniture/equipment, pharmacy, and 5-10 bed inpatient wards. They were capacitated for: maternal care (pre-natal and post-partum); malnutrition diagnosis and treatment; integrated management of childhood illness (IMCI) protocols; childhood vaccinations, HIV diagnosis and treatment; and chronic care (NCD). Health Centers were staffed to GOR norms: 17 nurses, 2 laboratory technicians, and 9 other staff.[1,2] including social workers in six health centers that treated HIV. Staff received regular trainings in IMCI, urgent obstetrical neonatal care, malnutrition, HIV, TB, family planning, pre-natal care, and NCDs. They each strengthened registry and reports health management information system (HMIS), supply chains, and pharmacies. Staff received additional incentives through performance-based financing (PBF).
Comprehensive Community Health Worker System (800+)
Three community health workers (CHWs) served 2-3 villages (~80 to 150 households) in both districts with support from 2-5 higher educated supervisors in each Cell (4th-level administrative unit). CHWs were trained and equipped for community IMCI, maternal health, hygiene and sanitation, and malnutrition by the district hospital community health supervisor, and they reported monthly into a performance-based financing system.[3] In S. Kayonza, CHWs rounded every household once per month. HIV/AIDS, TB, and NCDs were managed by daily visits by one *accompagnateur* per 3 to 5 patients.

2. Survey design

Demographic and Health Surveys (DHSs) are standardized household surveys that have been conducted in dozens of countries worldwide roughly every five years since the early 1980s. DHSs focus on maternal and child health, and since the early 2000s, ask for blood samples from respondents to test for anemia, malaria, HIV, and other illnesses. The 2005 and 2010 DHSs in Rwanda were the third and fourth of their kind.

The 2005 Rwanda DHS selected 10,644 households representing urban and rural communities in each of the 12 old provinces, and the 2010 Rwanda DHS selected 12,792 households representing urban and rural communities in each of the 30 newly-defined districts. A two-staged cluster design was employed in which primary sampling units (PSUs) at the community-level were selected with probability proportionate to size. In the 2005 survey, 462 PSUs were selected from a list of enumeration areas generated by the 2002 census. In the 2010 survey, 492 PSUs were selected from a list of villages generated in preparation for the 2012 census.

In the second stage of sampling, household listing teams travelled to each of the selected PSUs and hand-mapped all dwellings. From each map, 20-24 households were systematically selected in 2005, and 13 households were systematically selected in 2010 with equal probability. A GPS coordinate of each PSU was recorded and randomly geographically displaced up to 5km in rural areas, and up to 2km in urban areas and camps, to anonymize the identity of respondents and their communities. In rural areas, one in every 100 PSUs was displaced up to 10km to ensure anonymity in sparsely populated areas.

In each selected dwelling, one adult was invited to complete a household questionnaire in which s/he reported household assets, and a listing of all household members with key demographic

characteristics. All women age 15 to 49 who were usual residents and slept in the dwelling the night before the interview were invited to complete the women's questionnaire which asked about health outcomes; personal sociodemographic characteristics; and about health and demographic characteristics of each child. Height and weight was measured in women and all children under age five who were present in the household. Men age 15 to 59 were also sampled, and additional protocols and questionnaire were used to collect blood samples for HIV and other blood testing.

Interviewers received three weeks of standardized training which included establishment of p rivacy for interviewing,[4] and ensuring informed, voluntary verbal consent before interviewing with the interviewer recorded her/his own signature and the date. Verbal, rather than written, consent was obtained because illiteracy is high in Rwanda. In 2005, 99.7% of households consented and responded, in which 98.1% of eligible women consented and responded. In 2010, 99.8% of households consented and responded, in which 99.1% of women consented and responded.

The household, woman, and man questionnaires are available in Appendix F of the 2005 and 2010 Rwanda DHS reports.[5,6] These surveys were implemented by the Rwanda Ministry of Health and Population with technical assistance from ICF International and funding from the USAID|MeasureDHS Project. Ethical review for this survey was provided by Governments of Rwanda and the USA.

3. Comparison Group & Propensity Score Matching

We performed two analyses to try to refine our choice of comparison group based on recommendation by Rubin.[7] First, we limited our comparison to other areas in Eastern Province (roughly the boundary of old Umutara district), located in proximity to the intervention area (roughly the boundary of old Kibungo district). However, southeast Rwanda (Kigungo) where the intervention area was located had a

higher under-five mortality rate than any other region of the country, including the rest of Eastern Province (Umutara), and comparison of indicators were mixed (Table s2).

Table s2. Summary of baseline health system output and health outcome indicators

	Kibungo (roughly K/SK)	Umutara (Rest of Eastern Prov)	Byumba	Ruhengeri	Gisenyi	Kibuye	Cyangugu	Gikongoro	Butare	Gitarama	Kigali Ngali	Kigali	Rural
HEALTH SYSTEM OUTPUTS													
CHILDREN													
Excl breastfeed mo	5.2	5.7	6.1	6.3	6.0	6.1	4.7	6.8	5.8	5.1	5.8	3.7	5.8
DPT3 vaccine	85.6	89.7	81.5	93.1	79.5	96.3	79.8	95.0	92.2	90.6	83.4	80.0	87.3
Measles vaccine	73.9	74.6	85.7	93.0	74.4	92.4	87.5	93.0	94.9	94.0	80.7	85.5	85.0
ARI & treated	22.5	23.8	31.4	29.2	20.0	17.6	20.5	15.3	28.5	39.1	26.8	46.7	24.5
Diarrhea & ORT	27.5	30.2	24.6	29.1	33.8	34.8	31.7	36.9	33.7	40.2	28.5	44.1	30.8
Fever & antimalarial	18.5	16.7	8.1	5.1	2.5	1.5	15.8	2.8	14.1	31.8	22.1	9.0	12.6
WOMEN													
1+ ANC	97.1	95.9	95.9	95.7	93.0	93.6	92.6	93.4	94.2	96.8	91.5	92.2	94.7
Skilled attendance	46.0	40.4	30.6	32.3	28.6	28.8	52.6	18.6	45.9	48.7	31.2	70.3	34.6
Caesarean	2.2	2.1	1.7	1.7	1.8	2.0	5.3	1.7	2.6	5.3	0.8	11.5	2.2
PNC 48 hours	1.8	4.1	5.2	2.0	6.9	0.8	3.7	1.7	2.1	7.8	1.6	8.3	3.5
Unmet need	37.0	40.3	36.8	44.2	38.3	39.2	38.1	38.5	38.2	36.3	35.8	29.2	38.4
Modern contraception	10.0	8.2	9.6	8.7	10.1	8.2	13.1	4.3	6.4	12.9	8.2	28.0	8.6
HEALTH OUTCOME													
CHILDREN													
ARI	27.3	16.6	24.9	13.4	14.9	8.8	21.0	19.2	21.3	13.1	6.1	20.4	16.9
Diarrhea	18.5	14.5	16.2	16.6	13.8	7.5	16.9	17.6	19.7	7.2	7.5	12.3	14.4
Fever	38.5	28.6	22.2	27.7	26.2	12.5	28.0	28.0	37.9	22.1	13.9	26.6	26.4
Stunting	43.2	38.6	49.0	53.4	47.4	53.2	41.5	55.8	40.2	42.8	43.9	28.2	47.3
Wasting	3.4	4.0	4.2	2.9	1.8	2.8	4.0	5.8	5.3	4.2	4.3	6.7	3.9
U5MR (0-9 years)	232	207	182	196	178	150	184	163	213	155	186	98	192
IMR (0-9 years)	127	111	97	101	92	86	122	97	124	97	105	54	108
NNMR (0-9 years)	45	44	51	45	34	50	50	48	46	48	44	24	46
mCCI (calculated)	60.3	59.9	59.3	60.5	56.8	60.8	60.7	59.5	64.0	67.0	58.9	69.8	60.1

Source: 2005 Demographic and Health Survey Final Report [5]

Secondly, we used propensity score matching with inverse probability of treatment weights to identify a comparison group from all other rural areas. However, propensity score matching did not result in a balanced comparison group (Table s3).

Table s3. Summary of balancing diagnostics for different potential comparison groups

Matching Scheme	Mean Bias	Median Bias	B	R
KSK versus ORA	78.9	40.6	341*	0.5
KSK versus Eastern Province†	133.0	52.3	303*	32.0*
KSK versus matched from ORA	15.4	14.7	146*	74.7*

* if B>25%, R outside [0.5,2.0]
† Average rainfall in July and October omitted from matching exercise because lack of variability in values predicted data perfectly

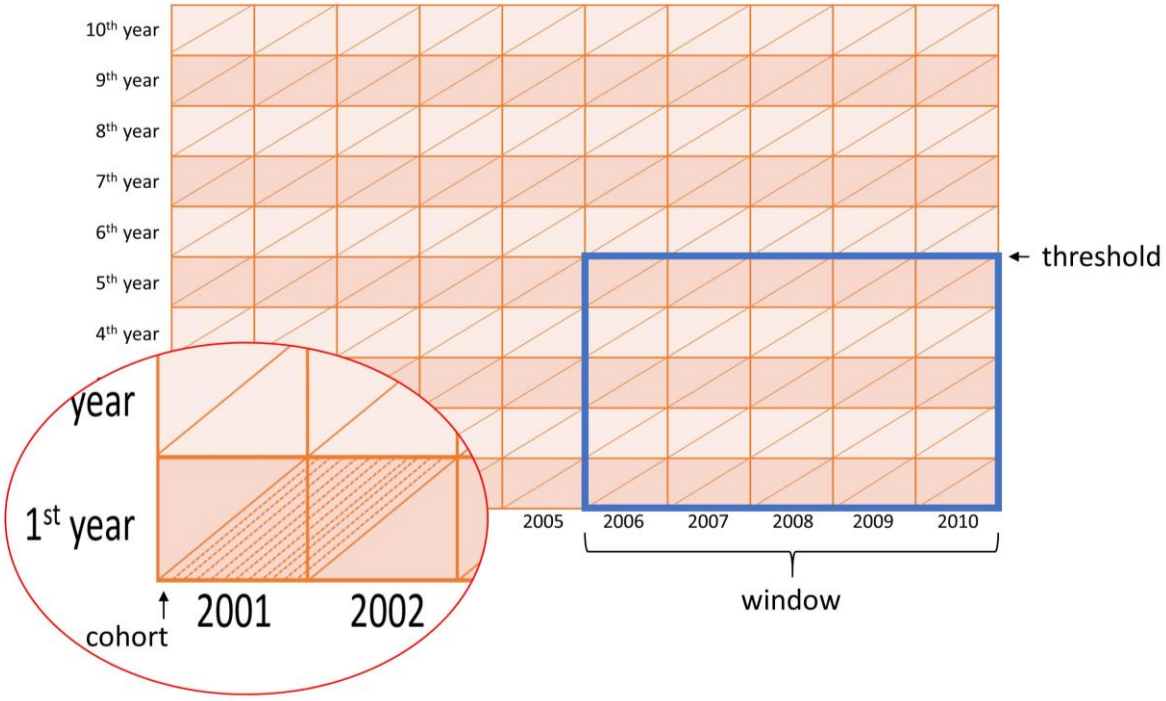
Thus, we used all other rural areas as a comparison to maximize sample size, and adjusted models for household wealth and woman's age which differed between Kirehe/S. Kayonza and other rural areas at baseline.

4. Mortality estimates

Mortality is estimated using synthetic cohort lifetables based on women's report of complete birth histories of all of their own births ("birth roster" generates childhood mortality estimates) and all of their mothers' births ("sibling roster" generates adult mortality estimates) as recommended by The MeasureDHS project.[8] In the birth roster, women are asked to report the month and year of each child's birth, whether they are alive at the time of interview, and if not, the child's age at death. Age is recorded in days for children under 30 days, in months for children 1-23 months, and in years for 24 months and higher. The MeasureDHS project imputes month and year of death based on this information for all children/siblings who died. Error is introduced when mothers do not remember exact birth or death dates, or they round ages to the nearest month or year. Missing ages are imputed using a "hot deck" method which means that the age of death is taken from the first preceding person in the dataset who has the same birth order and age-of-death type (day, month, year).

The life table approach tracks counts of individuals in one-month or one-year age cohorts as they age through a time window up to a certain age threshold. All mortality rates in this analysis were generated with the last five-year window of data. The window starts five years before the date of the first interview and ends on the date of the first interview.

Figure s1. Diagram of data contributing to under-five mortality synthetic life table estimate



Childhood mortality calculations are based on one-month cohorts. Children under age five born more than five years ago are truncated and start contributing person-months to the analysis when they enter the five-year window. The threshold age for neonates is one month, for infants it is 12 months, and for children under age five it is 60 months.

Neonatal mortality: number of deaths before age 1 month, divided by the cumulative person-months lived before age 1 month in the last five years, multiplied by 1000

Infant mortality: number of deaths before age 12 months, divided by the cumulative person-months lived before age 12 months in the last five years, multiplied by 1000

Under-five mortality: number of deaths before age 60 months, divided by the cumulative person-months lived before age 60 months in the last five years, multiplied by 1000

In the adult analysis, mortality calculations are based on one-year cohorts. Siblings alive five years before the first interview start contributing person-years to the analysis when they enter the window. There was no age threshold for adult mortality estimates.

Adult mortality: number of deaths, divided by cumulative person-years lived in the last five years, multiplied by 10,000

5. Difference-in-difference models

A linear regression model was used to compare trends in the intervention area with trends in the comparison area between 2005 and 2010. Equation 1 is a classic difference-in-differences model with binary values for time and group membership. When a binary outcome is analyzed with this linear model, the time-group interaction term effect estimate can be directly interpreted as the proportion difference-in-differences. Although binary outcomes follow a binomial distribution and should be analyzed with a logit or logistic model, *differences* between a binary outcome at time 0 and time 1, or between group 0 and group 1, follow a normal distribution and can be analyzed with a linear model.[9]

$$y_i = \beta_0 + \beta_1(t_i) + \beta_2(g_i) + \beta_3(t_i * g_i) + \boldsymbol{\beta}_{4\ldots k}(\boldsymbol{X}_i) \quad (1)$$

Where:

y_i binary outcome of interest for individual *i*

β_0 intercept

β_1 effect size of time between 2005 and 2010

β_2 effect size of intervention group compared to comparison group

β_3 difference-in-differences effect size (can be directly interpreted as the DID proportion)

$\beta_{4...k}$ matrix of effect sizes corresponding with covariates

t_i year in which individual *i* was interviewed (2005=0, 2010=1)

g_i group to which individual *I* belongs (comparison=0, intervention=1)

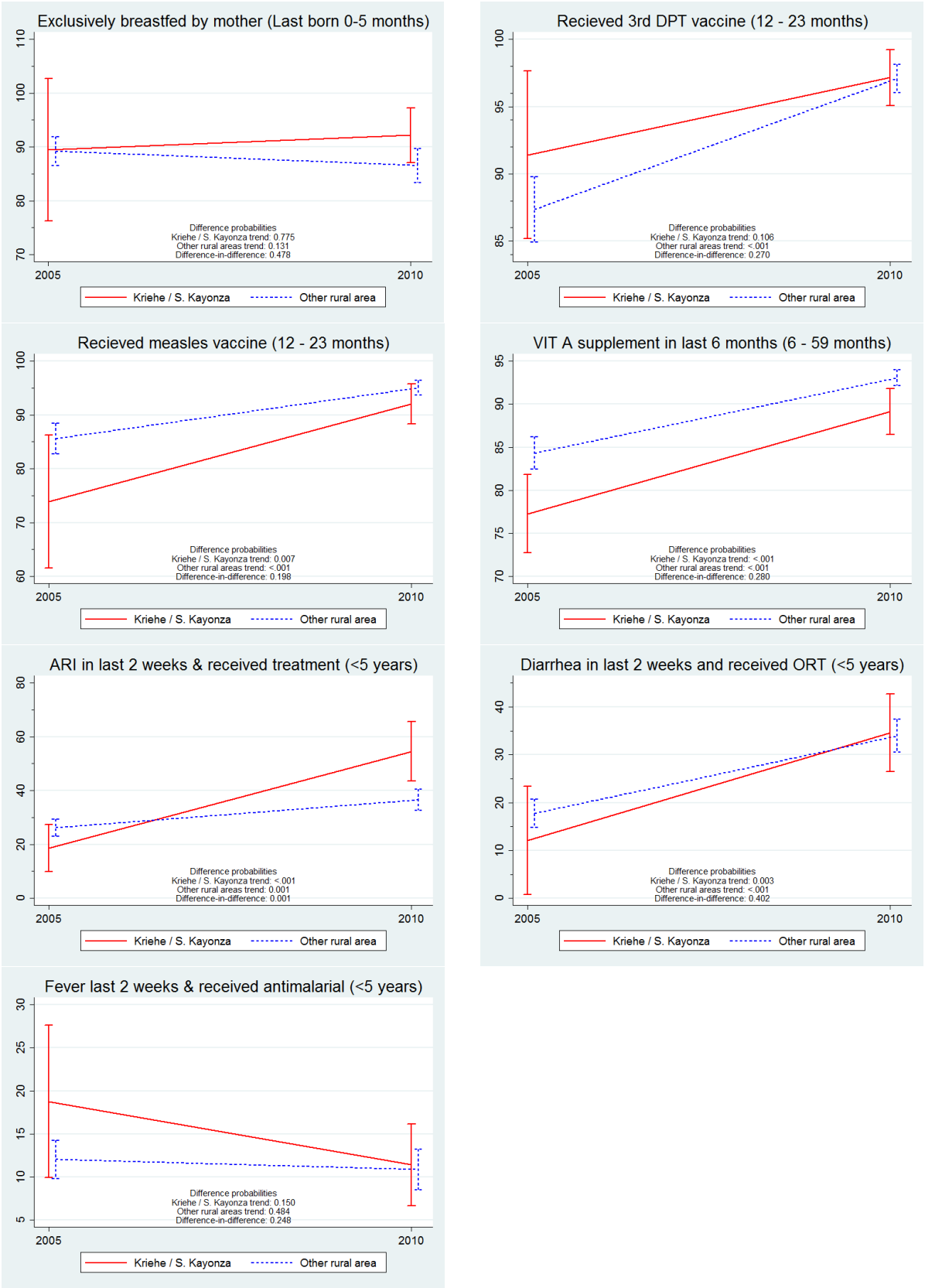
This model was implemented in Stata using svyset commands to adjust for clustering of observations in primary sampling units, and sampling probability weights.

We provide an excerpt of this Stata code below which can be adapted in other similar program evaluations. Before modeling, we appended the 2005 and 2010 datasets and generated a series of variables. In this model, "subpop_outcome" is binary where 1 identifies individuals included in the subpopulation and 0 identifies individuals excluded from the subpopulation; "outcome" is binary where 1 identifies a characteristic like diarrhea is present and 0 otherwise; "group" is binary where 0 identifies individuals in the comparison group and 1 identifies individuals in the intervention group, "time" is binary where 0 identifies individuals in the 2005 survey and 1 identifies individuals in the 2010 survey; "mother_age" is v012 representing age in years, and "hh_wealth" is v190 representing a continuous value of household wealth.

```
generate weight = v005/1000000
svyset [pweight = weight], psu(v021)
svy, subpop(subpop_outcome): regress outcome i.group i.year i.group#i.year mother_age hh_wealth
```

168 *6.* Comparison of trends graphs

169 Figure s2. Health System Outputs 2005-2010 in Kirehe/S. Kayonza and Other Rural Areas, Children



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171 Figure s3. Health System Outputs 2005-2010 in Kirehe/S. Kayonza and Other Rural Areas, Women

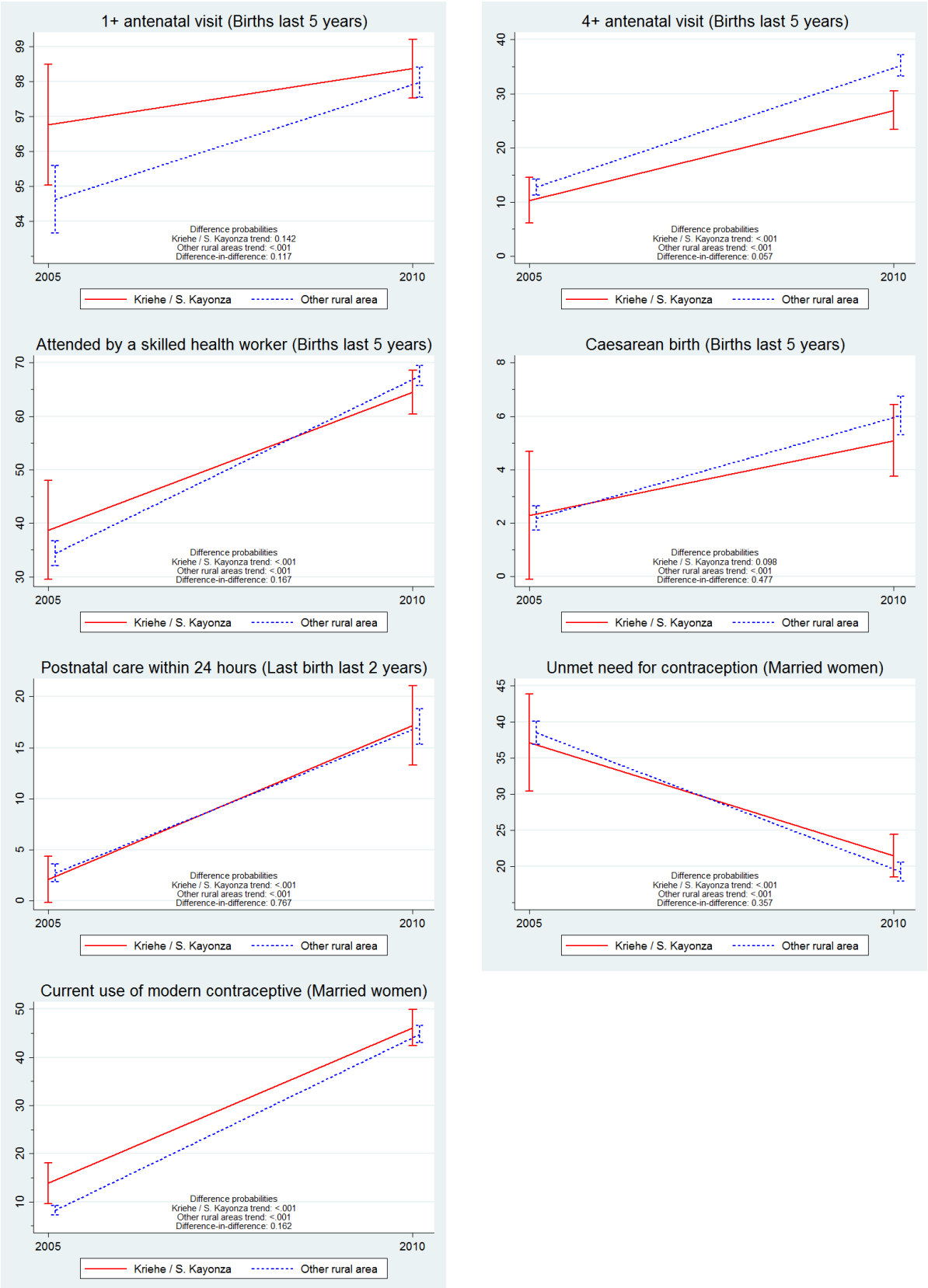

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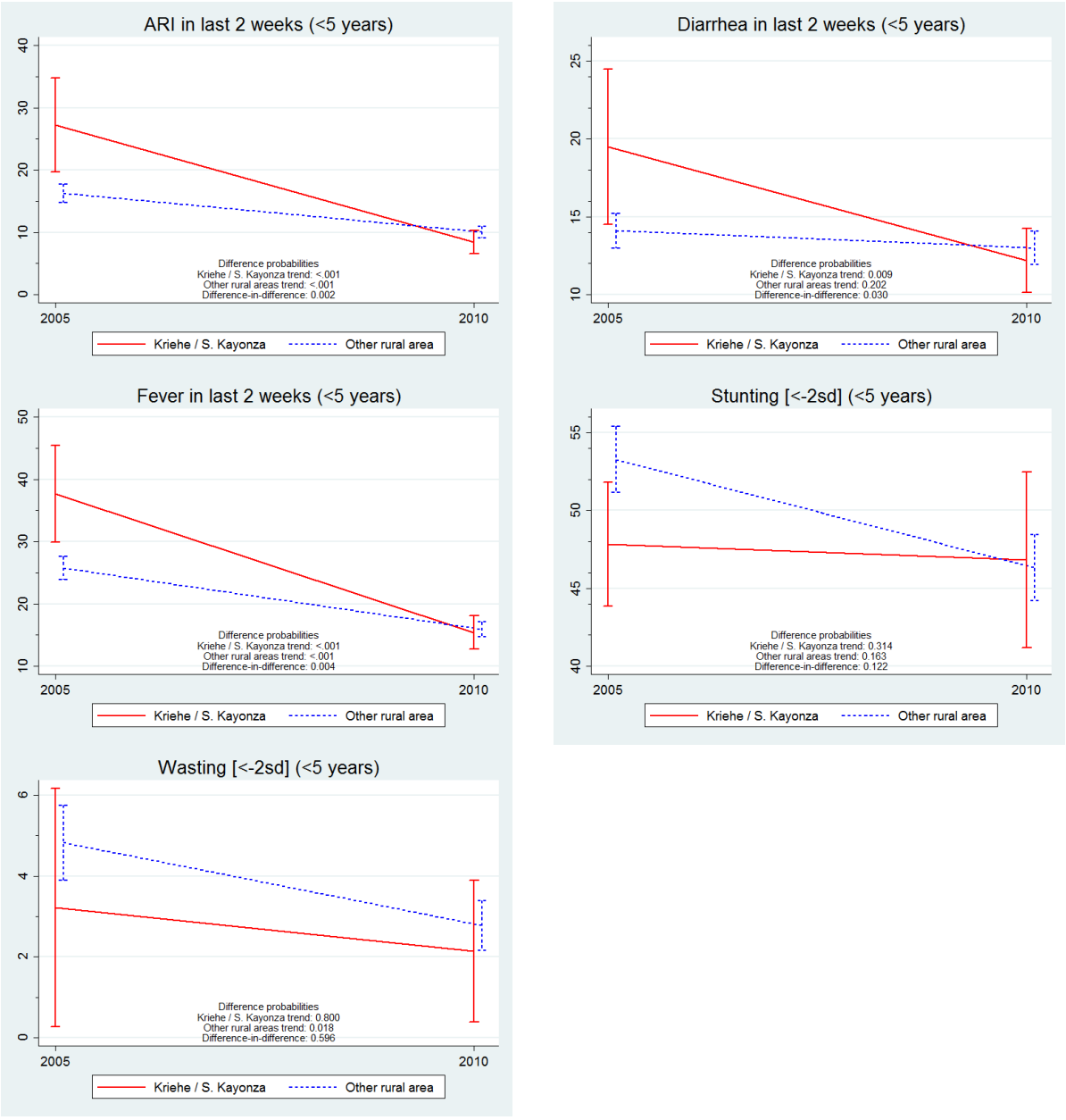
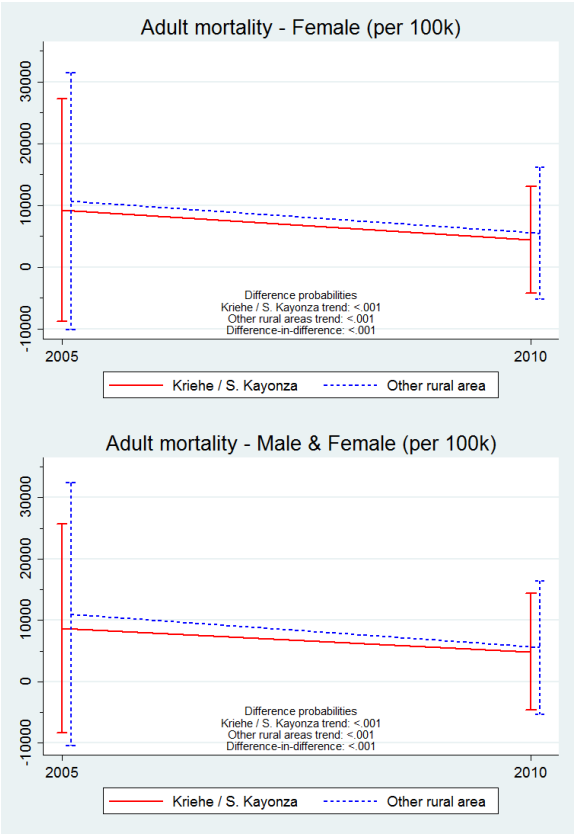
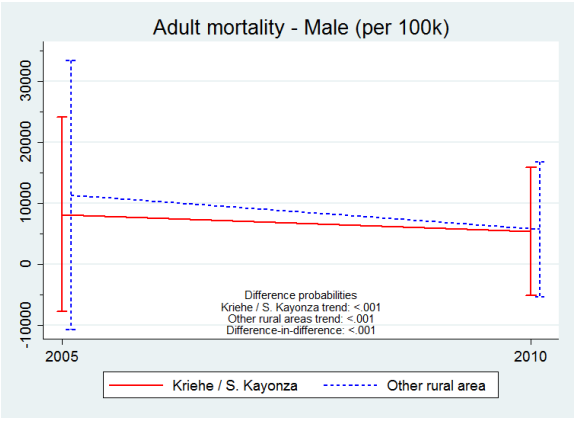
Figure s4. Child Health Outcomes 2005-2010 in Kirehe/S. Kayonza and Other Rural Areas



177 Figure s5. Adult Health Outcomes 2005-2010 in Kirehe/S. Kayonza and Other Rural Areas





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