Appendix for paper "Foreign aid to rural healthcare centers associated with improved service provision and did not crowd out government investments: a case study in Rwanda"

Chunling Lu, Benjamin Cook, Chris Desmond

Section 1 Constructing index variables

Using binary variables in the DHSST about the availability of a service (1= available, 0 otherwise) in a health center, we constructed two index variables to measure the level of services for child and maternal care as well as the services for HIV, TB, and malaria (Equation 1).

$$\text{Index} = \sum_{i=1}^{n}(service\ i) \qquad\qquad (1)$$

For example, the survey asked about availability of 31 services for HIV, TB and malaria in health centers. If a health center provided 16 of them, then the index for HIV/TB/malaria in this health center was 16.

Section 2 Multilevel mixed-effects model for association between government investments and foreign funds, and between service provision index and foreign funds

To process the panel data model, we first checked for the presence of autocorrelation in each health center's panel data with the Woodridge test. The results of the F test showed that the hypothesis of zero correlation between error terms within health centers was not rejected for both government investments (p=0.67) and service provision indices (p=0.36 for child and maternal care, and p=0.47 for HIV, TB, and malaria care).

In our analysis, a three-level model is used to capture four sources of variation in the government investments: health-center level factors, health-center level clustering effects, district-level clustering effects, and random effects. We specified the multilevel random-effects model with health center i nested within district j, and characterized it as follows:

$$Log(Gov\_pc_{ijt}) = \beta_{0j}X_0 + \beta_1\ Log(Aid\_pc_{ijt}) + \beta_2Log(Other\_pc_{ijt}) + \beta_3Poor_{ijt} + \beta_4Owner_{ij}$$
$$+ \beta_5Year_t + \varepsilon_{ijt} \qquad\qquad (2)$$

$$\beta_{0i} = \beta_0 + \mu_{0i} + v_{0ij} \qquad\qquad (3)$$

where Gov_pc_{ijt} represents the per capita government investment in ith health center of the jth district at year t, X_0 is a constant, Aid_pc_{ijt} represents per capita funds received directly from donors by ith health center in the jth district at year t, $Other\_pc_{ijt}$ represents the per capita funds received directly from other sources by ith health center in the jth district at year t. $Poor_{ijt}$ is the percentage of indigent population in the ith health center of the jth district at time t. $Owner_{ij}$ is the ownership of the ith health center in the jth district. $Year$ is a year indicator. The random effects of the model are represented by v_{0j} that measures clustering effects at the district level and v_{0ij} that measures clustering effects at the health center level. The random errors at the health-center level are captured by $\varepsilon_{ijt.}$

We specified a multilevel random-effects model to identify the association between service provision index and aid as follows:

$$Log(Index_{ijt}) = \beta_{0j}X_0 + \beta_1Log(Aid\_pc_{ijt}) + \beta_2Log(NonAid\_pc_{ijt}) + \beta_3Poor_{ijt} + \beta_4Owner_{ij}$$
$$+ \beta_5Year_t + \varepsilon_{ijt} \qquad\qquad (4)$$

2

$$\beta_{0i} = \beta_0 + \mu_{0i} + v_{0ij} \tag{5}$$

where $index_{ijt}$ represents the index of child and maternal care (or index of HIV, TB, malaria care) in ith health center of the jth district at year t, Aid_pc_{ijt} represents per capita funds received directly from donors by ith health center in the jth district at year t, $NonAid\text{-}pc_{ij}$ represents the per capita funds received directly from other sources by ith health center in the jth district at year t. $Poor_{ijt}$ is the percentage of indigent population in the ith health center of the jth district at time t. $Owner_{ij}$ is the ownership of the ith health center in the jth district. $Year$ is a year indicator. The random effects of the model are represented by v_{0j} that measures clustering effects at the district level and v_{0ij} that measures clustering effects at the health center level. The random errors at the health-center level are captured by $\varepsilon_{ijt.}$

Section 3 Sensitivity of results to various statistical methods

We conducted sensitivity analysis as presented **Appendix Table 3**. We varied the scale of the service index (in unit or log terms). In place of the random-effects model, we estimated a fixed-effects (at health center level) model. A fixed-effects model generates less biased estimates, whereas a random-effects model generates more efficient estimates.[1] In addition, we tested if there was a difference between assuming that service provision or government investments was influenced by the time of the *arrival* of foreign funds and assuming that service provision or government investments was influenced by the *expectation* of receiving foreign funds in a given budget cycle. The second assumption is tested using models with a one-year lagged aid variable. With all these variations, we generated 4 sets of regression results for additional analysis and 16 sets of regression results for service provision analysis.

Supplementary Reference
1. Wooldridge JM. Introductory Econometrics: A Modern Approach. 5th ed. Mason, OH: South-Western; 2013: 466–478.

Appendix Table 1 List of child and maternal services and HIV, TB, and malaria services

Services related to child and maternal care	% health centers with service available in 2011 (n = 330)
Promotion for vaccination and immunization	100%
Promotion on ante-natal care	98%
Promotion on family planning	98%
Promotion for growth monitoring	96%
Promotion on post-natal care	95%
Education campaigns on family planning	92%
Malnutrition Screening for Children Under 5	91%
The clinical service of Deliveries - for normal pregnancy	91%
This facility offers any food programs	91%

Promotion of PMTCT	91%
Neonatal service of Post-Eutocic delivery care	91%
Full Vaccine (BCG, measles, pneumococcal polio0, Polio 1 DTC-HepB)	89%
Ready-to-Use Therapeutic Foods (RUTF) is offered as outpatient food support	87%
Education campaigns on hygiene	87%
Nutrition education community outreach	84%
Providing mebendazole to children with malnutrition	83%
Education campaigns on: Nutrition	82%
Providing vitamin to children with malnutrition	78%
Providing HIV care to children with malnutrition	78%
Inpatient food support is offered to Vulnerable patients	77%
Education campaigns on WASH (Water, sanitation, and hygiene)	76%
Providing vaccine to children with malnutrition	75%
Vitamin A Supplements for Children	75%
Education campaigns on Maternal health	75%
The facility have demonstration gardens	75%
Growth Monitoring for Children (Weight for Age)	73%
After delivery, Vitamin A for Mothers	73%
Education campaigns on IMCI	72%
After delivery, Medication for Controlling Hemorrhage is offered	71%
Neonatal service of Breastfeeding support	69%
Oral Rehydration Salts Distribution	68%
Clinical service of Integrated Management of Childhood Illness	65%
Neonatal service of Neonatal Resuscitation	62%
The clinical service of Post-abortion care	60%
The facility have demonstration kitchen	58%
Pregnant Women have access to Voluntary Counseling and Testing (VCT) for HIV	57%
HIV/AIDS patient nutrition program	56%
Neonatal service of Newborn Checkups	55%
Inpatient food support is offered to	55%
Pregnant Women have access to Provider Initiated Testing as this facility	54%
The clinical service of Nutritional Rehabilitation	54%
Providing TB care to children with malnutrition	53%
Clinical service of Newborn care	52%

Children have access to Provider Initiated Testing	45%
Other than food support, the facility offer Animal Husbandry (Breeding)	42%
Other than food support, the facility offer cooperatives	41%
Children have access to Voluntary Counseling and Testing (VCT) for HIV	40%
Providing amoxy to children with malnutrition	37%
Providing iron to children with malnutrition	35%
Providing folic acid to children with malnutrition	35%
Expectant mother nutrition program	34%
Lactating mother nutrition program	34%
Schoolchild Feeding Programs	31%
Other than food support, the facility offer Agricultural training	30%
Inpatient food support is offered to pregnant women	24%
Ready-To-Use Therapeutic foods for adults	22%
Other than food support, having Income-Generating project	22%
Neonatal service of Neonatal Sepsis treatment	18%
The facility provide inpatient nutritional rehabilitation to patients	16%
Indigent nutrition program	16%
The facility have a canteen to offer food to patients	15%
The adult nutrition monitoring service	14%
Other than food support, the facility offer Agricultural Inputs	12%
The children nutrition service of Schoolchild Health Monitoring	10%
The clinical service of Obstetrics and management of dystocic pregnancies	10%
Nutrition monitoring in school	9%
Inpatient food support is offered to indigents	8%
HIV, TB, Malaria services	
Expectant mothers receive Insecticide Treated Nets (ITN/LLIN) directly from the facility	96%
Education campaigns on Tuberculosis	92%
The clinical service on Malaria	92%
Education campaign on malaria	91%
Promotion of PMTCT	91%
The additional service of Voluntary Counseling and Testing (VCT/PIT)	91%
1st line drug-resistant TB treatment	86%
Education campaigns on: PMTCT/VCT	86%

The clinical service on TB	85%
Education campaigns on: HIV/AIDS	83%
Education campaign on insecticide-treated nets	82%
Education campaigns on: Sexually Transmitted diseases	78%
Providing HIV care to children with malnutrition	78%
The clinical service on HIV/AIDs	77%
The additional service of Provider Initiated testing	72%
The additional service of Pre-marital HIV Testing and Consultation	66%
Vulnerable Patients have access to provider initiated testing	61%
Pregnant Women have access to VCT	57%
The adult nutrition service of HIV/AIDS patients	56%
Active TB treatment	55%
The family planning methods of Condom is supplied by community health workers	55%
Vulnerable Patients have access to VCT	54%
Pregnant Women have access to Provider Initiated Testing	54%
Providing TB care to children with malnutrition	53%
2nd line drug-resistant TB treatment	47%
Children have access to Provider Initiated Testing	45%
Children have access to VCT	40%
Indigents have access to VCT	38%
Latent TB treatment	25%
Nurse prescribes ART at this site	21%
The clinical service of Circumcision	13%

VCT: Voluntary Counseling and Testing
PMTCT: Prevention of mother-to-child transmission
IMCI: Integrated Management of Childhood Illness

Appendix Table 2 Summary statistics of variables

| Variable	N	Mean	Standard Deviation	Minimum	Maximum
Index of child and maternal care	990	29.96	9.00	6	59
Index of HIV, TB, and malaria care	990	14.05	6.11	2	30
Total funds received (in 2009 US$)	990	107,327	56,532	5,576	415,606
Funds from donors directly (in 2009 US$)	990	25,523	30,374	0	375,955

Funds from non-donors directly (in 2009 US$)	990	81,804	44,528	1,242	79,711
Funds from governments directly (in 2009 US$)	990	32,169	23,520	0	327,303
Owned by governments	990	0.61	0.49	0	1
% of indigent population	990	0.085	0.07	0	0.61

Variable	N	Mean	Standard Deviation	Minimum	Maximum
2009					
Index of child and maternal care	330	24.45	5.60	7	41
Index of HIV, TB, and malaria care	330	10.73	3.132	2	17
Total funds received (2009 USD)	330	90,350	49,893	5,576	391,972
Funds from donors directly (2009 USD)	330	17,588	24,178	5	297,389
Funds from non-donors directly (2009 USD)	330	72,762	42,269	5571	379,711
Funds from government directly	330	26,872	21,827	5	327,303
Owned by governments	330	0.61	0.49	0	1
% of indigent population	330	0.08	0.05	0	0.47
2010					
Index of child and maternal care	330	26.82	5.82	6	43
Index of HIV, TB, and malaria care	330	10.79	3.35	2	18
Total funds received (2009 USD)	330	107,626	58,572	8,533	415,606
Funds from donors directly (2009 USD)	330	24,810	33,687	5	375,955
Funds from non-donors directly (2009 USD)	330	82,816	45,882	4973	355,809
Funds from government directly	330	31,673	27,360	5	306,700
Owned by governments	330	0.61	0.49	0	1
% of indigent population	330	0.08	0.06	0	0.56
2011					
Index of child and maternal care	330	38.63	7.90	17	59
Index of HIV, TB, and malaria care	330	20.62	5.15	4	30
Total funds received (2009 USD)	330	124,005	55,847	8,361	319,871
Funds from donors directly (2009 USD)	330	34,170	30,256	5	237,532
Funds from non-donors directly (2009 USD)	330	89,834	43,825	1242	265,553
Funds from government directly	330	37,960	19,389	5	118,303
Owned by governments	330	0.61	0.49	0	1
% of indigent population	330	0.10	0.10	0	0.61

Appendix Table 3 Analytical framework

	Variants considered	Number of variants
Dependent variables (in absolute or log terms)	Service provision index for child and, maternal care	4
	Service provision index for HIV, tuberculosis, and malaria	
Estimation methods	Fixed-effects	2
	Multilevel random-effects	
Assumption on timing of aid effects	Same year	2
	One-year lag	
Total		16

Appendix Figure 1 Level of funds from various sources and their proportions across the three years (in 2009 USD)**,** Rural Rwanda 2009-2011
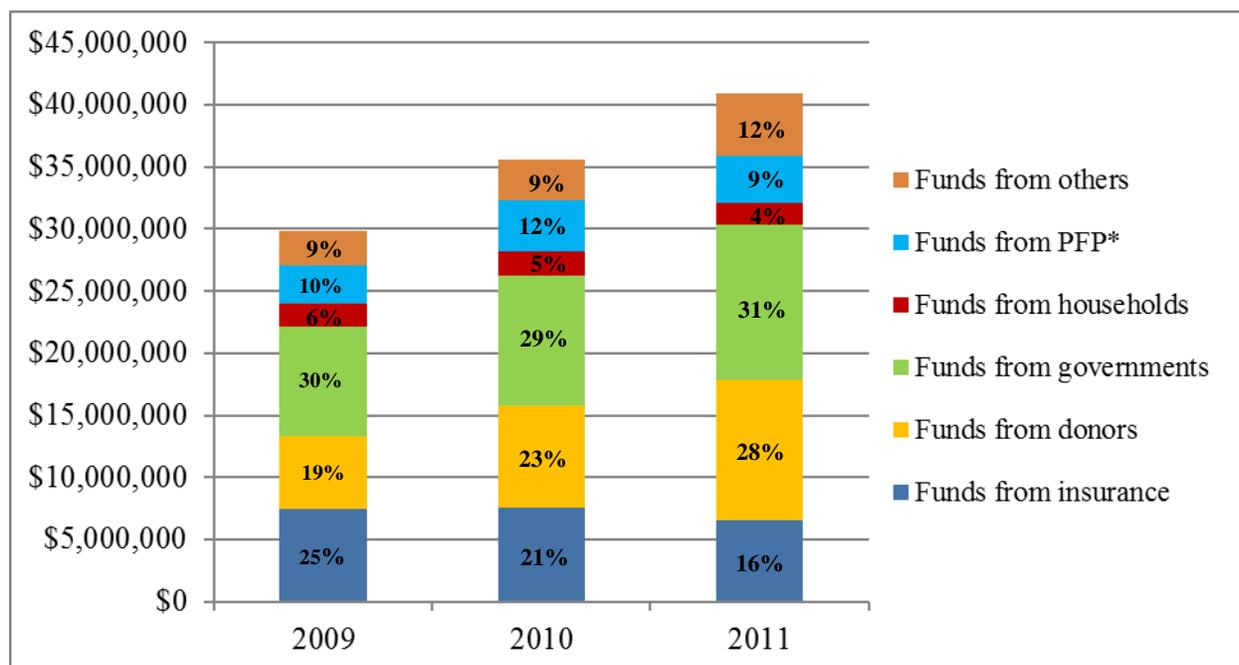
* PFP: pay-for-performance program.

Appendix Table 4 Estimated coefficients of DAH for service provision analysis assuming instant aid effect

	Coefficients (standard error)	
	Multilevel Random Effects	**Fixed-Effects**
1. Index of child and maternal care (CMindex)		
Log(CMindex)		
Log(donor funds per capita)	0.003 (0.003)	-0.002 (0.003)
CMindex		
Log(donor funds per capita)	0.044 (0.07)	-0.09 (0.09)
Observations	990	990
2. Index of HIV, TB, and malaria care (HTMindex)		
Log(HTMindex)		
Log(donor funds per capita)	0.006(0.003)*	-0.001 (0.004)
HTMindex		
Log(donor funds per capita)	0.06 (0.04)	-0.034 (0.05)
Observations	990	990

*: statistically significant at the 0.1 level.

Appendix Table 5 Regression results for the association between government investments and foreign aid in the 330 rural health centers between 2009 and 2011

Log(Govt.funds per capita)	Coefficient (95% confidence intervals)			
	Multilevel random-effects (ML)		**Fixed-effects model (FE)**	
	Instant aid effects	1-year lagged aid effects	Instant aid effects	1-year lagged aid effects
Log(per capita aid)	0.13***	-0.002	0.14***	-0.07
	(0.06 - 0.19)	(-0.053 - 0.050)	(0.06 - 0.22)	(-0.16 - 0.04)
Log (per capita other funds)	0.36***	0.34**	0.33**	0.28
	(0.10 - 0.62)	(0.041 - 0.63)	(0.001 - 0.65)	(-0.26 - 0.83)
% of indigent populations	0.68	1.35*	-0.23	0.49
	(-1.19 - 2.55)	(-0.03 - 2.75)	(-2.59 - 2.12)	(-1.69 - 2.68)
Reference group: owned by NGOs/FBOs				
Owned by governments	0.06	-0.08	-	-
	(-0.19 - 0.32)	(-0.38 - 0.22)	-	-
Reference group: 2009				
Year 2010	0.018	-0.24*	0.016	-0.29**
	(-0.19 - 0.23)	(-0.50 - 0.01)	(-0.21 - 0.24)	(-0.57 - -0.02)
Year 2011	0.19	-	0.20	-
	(-0.007 - 0.46)	-	(-0.08 - 0.48)	-
Constant	0.25	0.70***	-0.07	-0.10
	(-0.19 - 0.69)	(0.22 - 1.17)	(-0.40 - 0.26)	(-0.53 - 0.32)
Observations	990	660	990	660

*: statistically significant at the 0.1 level.

**: statistically significant at the 0.05 level.

***: statistically significant at the 0.01 level.

Appendix Table 6 Regression results for association between service provision and foreign aid assuming one-year lagged aid effects in the 330 rural health centers between 2009 and 2011

	Coefficient (95% confidence intervals)			
	Multilevel random-effects (ML)		**Fixed-effects model (FE)**	
	Log(CMindex)	log(HTMindex)	Log(CMindex)	Log(HTMindex)
Log(per capita aid)_LAG	0.008***	0.014***	0.007*	0.01*
	(0.002 - 0.014)	(0.004 - 0.023)	(-0.001 - 0.016)	(-0.002 - 0.021)
Log (per capita non-aid)_LAG	0.025	0.059**	0.013	0.018
	(-0.007 - 0.058)	(0.012 - 0.105)	(-0.04 - 0.07)	(-0.054 - 0.09)
% of indigent populations	-0.002	-0.27*	-0.11	-0.28
	(-0.26 - 0.26)	(-0.58 - 0.04)	(-0.40 - 0.17)	(-0.66 - 0.10)
Reference group: owned by NGOs/FBOs				
Owned by governments	-0.035*	-0.032	-	-
	(-0.07 - 0.07)	(-0.09 - 0.025)	-	-
Reference group: 2011				
Year 2010	-0.36***	-0.65***	-0.36***	-0.65***
	(-0.39 - -0.33)	(-0.69 - -0.61)	(-0.39 - -0.33)	(-0.69 - -0.61)
Constant	3.63***	2.97***	3.63***	3.0***
	(3.56 - 3.69)	(2.89 - 3.05)	(3.55 - 3.72)	(2.80 - 3.11)
Observations	660	660	660	660
Number of clusters (districts, health centers, ML)/R-squared (FE)	27/330	27/330	0.40	0.52
	CMindex[a]	HTMindex[b]	CMindex	HTMindex
Log(per capita aid)_LAG	0.26***	0.18***	0.27**	0.11
	(0.10 - 0.43)	(0.066 - 0.295)	(0.01 - 0.53)	(-0.06 - 0.27)
Log (per capita non-aid)_LAG	0.55	0.67**	-0.11	0.07
	(-0.38 - 1.49)	(0.083 - 1.26)	(-1.73 - 1.51)	(-0.94 - 1.09)
% of indigent populations	-1.17	-4.15*	-4.41	-4.40*
	(-9.31 - 6.97)	(-8.91 - 0.61)	(-12.98 - 4.14)	(-9.78 - 0.97)
Reference group: owned by NGOs/FBOs				
Owned by governments	-1.17*	-0.35	-	-
	(-2.45 - 0.09)	(-1.16 - 0.46)	-	-
Reference group: 2011				
Year 2010	-11.59***	-9.69***	-11.74***	-9.82***
	(-12.45 - -10.74)	(-10.25 - -9.13)	(-12.66 - -10.82)	(-10.4 - -9.25)
Constant	39.08***	20.83***	39.54***	21.1***

	(37.14 - 41.02)	(18.55 - 23.10)	(37.13 - 43.97)	(19.6 - 22.6)
Observations	660	660	660	660
# of clusters (health centers, districts, ML)/R-squared (FE)	27/330	27/330	0.43	0.57

*: statistically significant at the 0.1 level.
**: statistically significant at the 0.05 level.
***: statistically significant at the 0.001 level.
a: Index of child and maternal care
b: Index of HIV, TB, and malaria care

Appendix Table 7 Regression results for association between service provision and foreign aid assuming instant aid effects in the 330 rural health centers between 2009 and 2011

	Coefficient (95% confidence intervals)			
	Multilevel random-effects (ML)		**Fixed-effects model (FE)**	
	Log(CMindex)	log(HTMindex)	Log(CMindex)	Log(HTMindex)
Log(per capita aid)	0.003	0.006*	-0.002	-0.001
	(-0.002 - 0.008)	(-0.001 - 0.012)	(-0.008 - 0.005)	(-0.009 - 0.006)
Log (per capita non-aid)	0.009	0.036	-0.012	-0.0008
	(-0.027 - 0.045)	(-0.011 - 0.084)	(-0.052 - 0.028)	(-0.062 - 0.061)
% of indigent populations	0.032	-0.26*	-0.073	-0.33**
	(-0.18 - 0.24)	(-0.54 - 0.01)	(-0.28 - 0.14)	(-0.61 - -0.047)
Reference group: owned by NGOs/FBOs				
Owned by governments	-0.05**	-0.032	-	-
	(-0.09 - -0.01)	(-0.084 - 0.021)	-	-
Reference group: 2009				
Year 2010	0.09***	-0.01	0.098***	-0.001
	(0.06 - 0.12)	(-0.05 - 0.03)	(0.07 - 0.13)	(-0.038 - 0.039)
Year 2011	0.46***	0.65***	0.47***	0.67***
	(0.43 - 0.49)	(0.61 - 0.69)	(0.44 - 0.50)	(0.63 - 0.71)
Constant	3.19***	2.33***	3.18***	2.35***
	(3.13 - 3.25)	(2.26 - 2.41)	(3.12 - 3.24)	(2.26 - 2.43)
Observations	990	990	990	990
Number of clusters (districts, health centers, ML)/R-squared(FE)	27/330	27/330	0.41	0.48
	CMindex[a]	HTMindex[b]	CMindex	HTMindex
Log(per capita aid)	0.04	0.058	-0.09	-0.03
	(-0.09 - 0.18)	(-0.02 - 0.135)	(-0.26 - 0.08)	(-0.13 - 0.06)
Log (per capita non-aid)	0.02	0.26	-0.64	-0.27
	(-0.77 - 0.82)	(-0.21 - 0.72)	(-1.66 - 0.38)	(-0.95 - 0.40)
% of indigent populations	-0.64	-4.31**	-3.36	-5.01**
	(-7.32 - 6.03)	(-8.45 - -0.17)	(-10.07 - 3.34)	(-9.16 - -0.86)
Reference group: owned by NGOs/FBOs				
Owned by governments	-1.57***	-0.32	-	-
	(-2.69 - -0.44)	(-0.72 - 0.22)	-	-
Reference group: 2009				
Year 2010	2.34***	-0.007	2.52***	0.12

	(1.69 - 2.99)	(-0.39 - 0.38)	(1.86 - 3.17)	(-0.27 - 0.51)
Year 2011	14.13***	9.83***	14.49***	10.07***
	(13.2 - 15.0)	(9.24 - 10.42)	(13.57 - 15.41)	(9.49 - 10.66)
Constant	25.5***	11.08***	25.3***	11.38***
	(24.0 - 27.0)	(10.23 - 11.92)	(23.8 - 26.8)	(10.41 - 12.35)
Observations	990	990	990	990
Number of clusters (districts, health centers, ML)/R-squared(FE)	27/330	27/330	0.47	0.57

*: statistically significant at the 0.1 level.

**: statistically significant at the 0.05 level.

***: statistically significant at the 0.001 level.

a: Index of child and maternal care

b: Index of HIV, TB, and malaria care