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Introduction

This paper investigates the susceptibility of Orphaned and Vulnerable Children (OVC) towards fever and respiratory related illnesses and disentangles the complex associations that explain these health outcomes. Many children in Africa have become orphaned and vulnerable as a result of HIV/AIDS. By 2010, it is estimated that about 18 million children below age 18 would be classified as OVCs due to HIV/AIDS (UNICEF, 2005). In Rwanda, 220,000 children are estimated to have lost one or both parents because of HIV/AIDS (UNAIDS, 2008). The survival, growth and development of OVCs are greatly threatened as these children are subject to social neglect and discrimination (UNICEF, 2006).

The intra-household and environmental factors that affect the health status of OVCs are difficult to determine in Rwanda, which has not fully recovered from the impact of the 1994 genocide and periodic economic depression. The term "Orphaned and Vulnerable Children" has been used widely in the literature to describe children who have been orphaned or made vulnerable as a result of HIV/AIDS (Schenk et al., 2008; Skinner et al., 2006; Andrews et al., 2006; Stover et al., 2006; Bhargava & Bigombe, 2003; Matshalaga & Powell, 2002). However, there is no universal consensus to its definition (Skinner et al., 2006). We follow the definition used by the Rwandan Demographic and Health Surveys (RDHS) based on UN recommendations (UNICEF, 2005). OVCs are defined as those who (i) have lost one or both parents, (ii) one or both parents have been chronically ill for at least three months within the 12 months preceding the survey, (iii) live in a household where at least one adult (18-59

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years old) has been chronically ill for at least three months within the 12 months preceding the survey or (iv) live in a household where at least one adult (18-59 years old) has died in the past 12 months after being chronically ill for at least three months (Institut National de la Statistique du Rwanda & ORC Macro, 2005).

We focus on recent morbidity experiences of children under five years, specifically diarrhoea, cough, fever and Acute Respiratory Infection (ARI) symptoms as recorded in the 2005 RDHS. The predictor variables at the individual and household levels were selected based on the child survival and growth framework which classifies different proximate determinants associated with malnutrition and infections (Hatt & Walters, 2006; Sreeramareddy et al. 2006; Erhardt et al., 2006; Filmer, 2005; Boadi & Kuitunen, 2005; The Cebu Study Team, 1991; Mosley & Chen, 1984). Socioeconomic and environmental factors mediate the synergic interactions between malnutrition and infections through a set of proximate determinants. This study addresses the direct and indirect pathways through which OVCs get exposed to morbidity risks taking into account the interactive effect of a range of household and individual (proximate) factors.

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Data and Methods

Data on 3,747 children aged below 5 years extracted from the 2005 RDHS were considered for the present analysis. The survey collected detailed household data and other demographic and health information from women of reproductive ages. Data on child health were recorded for births that occurred during the five years preceding the survey (Institut National de la Statistique du Rwanda & ORC Macro, 2005). Children who were classified as OVCs constituted 9.7% of the sample.

The main response variables of interest are diarrhoea, fever, cough and Acute Respiratory Infection (ARI) symptoms reported for the last two weeks preceding the survey. The RDHS asked if the child had any difficulties in breathing, specifically

short, fast and unusual breaths. Children showing ARI symptoms were those who had been ill with a cough accompanied by short and rapid breathing. The response variables were dichotomous with children who experienced an illness coded "1" and "0" otherwise. The recall errors are assumed to be minimal since the events in question relate to a short period before the survey.

We used Graphical Chain Modelling (GCM) for the analysis. GCM is ideal for identifying direct and indirect determinants using regression models (Cox and Wermuth, 1996). This technique enables one to present the structure of associations in graphical form and enhances our understanding of the direct and indirect pathways of associations which are often difficult to capture in conventional regression modelling. The reader is referred to Wermuth (2005) and Lauritzen (1996) for a more detailed discussion on GCM. The explanatory variables were grouped into three blocks: (i) individual and household demographic and socio-economic factors; (ii) intermediate (proximate) factors and (iii) primary exposure variable (Figure 1). Prenatal and delivery care were selected as proxies to reflect access to healthcare (Whitehead et al., 1997). Source of drinking water and access to toilet facilities are considered proxies to ascertain the influence of health-related environment. Nutritional measures such as stunting and wasting considered important were not included in the analysis because anthropometric data for about 56% of children were recorded missing in the individual data file for various reasons, for example the child died or was away or living elsewhere at the time of survey. The statistical software used for the analysis was GraphFitI (Blauth & Pigeot, 2000).

[---Figure 1 about here---]

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Results

Descriptive statistics

Table 1 shows the prevalence of diarrhoea, fever, cough and ARI symptoms among OVCs and non-OVCs. The distributions show that the prevalence of all four illnesses is higher among OVCs than non-OVCs. Chi-squared test revealed a significant difference in the prevalence of diarrhoea, fever and ARI symptoms between OVCs and non-OVCs at the 5% level but not for cough.

[--- Table 1 about here---]

Associations among the outcome variables

Figure 2 show that there exist direct associations among diarrhoea, fever and ARI symptoms but not between ARI symptoms and cough. The associations between diarrhoea, fever and cough imply that children who experienced diarrhoea are also more likely to experience fever and ARI symptoms and vice versa. The estimates presented in Table 2 show a positive association between cough, fever and diarrhoea, implying that a child who had diarrhoea is more likely to have a cough and or experience feverish conditions. About 54% of children who had diarrhoea also had fever, while 60% of those who had diarrhoea also had a cough. There is also a positive association between ARI symptoms, fever and diarrhoea which suggests that children who experience ARI symptoms are more likely to suffer from diarrhoea and fever. About 71% of all children who experienced ARI symptoms also had a fever. The associations are significant at the 1% level and remained significant even after adjusting for other relevant explanatory variables (Table 2).

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Direct determinants of diarrhoea, fever, ARI symptoms and cough

Figure 2 shows the direct determinants of diarrhoea, fever, ARI symptoms and cough. The green, pink, yellow and blue arrows show the direct associations of the pure explanatories, the intermediate factors and the primary exposure variable with diarrhoea, fever, ARI symptoms and cough, respectively. The figure shows that OVC status has a direct association with diarrhoea, fever and ARI symptoms but not with cough. The associations persist after accounting for demographic and socio-economic factors and are significant at the 5% level. OVCs have increased odds of experiencing diarrhoea (48%), fever (30%) and ARI symptoms (39%) compared to non-OVCs (Table 2).

The chain graph shows that, after accounting for OVC status, the intermediate factors directly associated with diarrhoea are breastfeeding, source of drinking water and prenatal care. Children who were not breastfed, those whose mothers received skilled prenatal care and those who live in households with access to safe drinking water are significantly less likely to have diarrhoea (Table 2). The pure explanatories directly associated with diarrhoea are age and sex of the child, the household structure and educational status of the mother/carer. Younger children have significantly higher odds of having diarrhoea compared to those aged 48-59 months (Table 2). The results also show that male children have increased odds (33%) of having diarrhoea compared to female children. Children who lived in households with fewer adults have increased odds of having diarrhoea compared to children who live in households with four or more adults. Also, if a child's mother/carer has no formal education, his/her odds of having diarrhoea increases by 37% compared to a child whose mother/carer has secondary or higher education.

The chain graph shows that the only intermediate factor that has a direct association with fever is prenatal care (Figure 2). As expected, a child whose mother

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received skilled prenatal care has reduced (20%) odds of having fever compared to a child whose mother received unskilled or no care. The pure explanatories that have direct association with fever are age of the child, household structure and natural region. The odds ratio shows that younger children are more (27%) susceptible to fever (Table 2). Children who lived with three or less adults, those residing in the lake and marshy Southern and Eastern regions are also more susceptible to fever compared to those who live with four or more adults and those who reside in the City of Kigali.

The intermediate factors directly associated with children showing ARI symptoms are breastfeeding and prenatal care received by the mother (Figure 3). Currently breastfed children and those whose mothers received unskilled prenatal care have higher odds (45% and 22% respectively) of showing symptoms of ARI compared to non breastfed children and those whose mothers received skilled prenatal care (Table 2). After adjusting for OVC status and the intermediate factors, the pure explanatories directly associated with ARI symptoms are the age of the child, birth interval and household structure. Younger children, those with lower preceding birth interval and those living with fewer adults in the household have higher odds of showing ARI symptoms.

Cough unlike diarrhoea, fever and ARI symptoms does not have a direct association with OVC status, even after adjusting for other significant factors. The only intermediate factor directly associated with cough is mothers' prenatal care status (Figure 2). Children whose parents received skilled prenatal care have reduced odds of having a cough (Table 2). The pure explanatories directly associated with cough, after adjusting for the other morbidities and prenatal care, are the age of the child, the number of household members, the region and place of residence. Also, the odds of having a cough are higher among younger children, children in households with 7 or

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more members and those residing in urban areas and the Southern region and City of Kigali.

[---Table 2 and Figure 2 about here---]

Indirect determinants operating through OVC status

The red arrows in Figure 3 show the intermediate factors and pure explanatories which operate through OVC status to influence childhood morbidity (diarrhoea, fever and ARI symptoms). The chain graph shows that vaccination, type of toilet facility and prenatal care operate through OVC status to influence childhood morbidity. Note that prenatal care operates directly and also indirectly to influence childhood morbidity. However type of toilet facility and vaccination only operate indirectly through OVC status. This suggests that the poor health outcomes of OVCs are also attributable to their vaccination status, environmental hygiene and access to healthcare (Table 3).

The pure explanatories that operate through OVC status to influence health outcomes of children are the age and sex of the household head, educational status of the mother/carer, natural region and place of residence (Figure 3). OVCs are more likely to be found in households headed by elderly persons (40+ years) and females, where the mother/carer has inadequate education and are more likely to be in urban areas and the south and eastern regions of the country (Table 3). This is an indication that the household structure of OVCs, their mother's/carers educational status and place of residence also contribute to their poor health outcomes.

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Indirect determinants operating through intermediate factors and OVC status

Figure 3 show the pure explanatories that influence childhood morbidity through the intermediate factors (vaccination, prenatal care and toilet facility) and OVC status. The pure explanatories that operate through the intermediate factors and through OVC status to influence child morbidity are age of the child, age and sex of the household head, birth order, educational status of the mother/carer, number of household members, natural region and place of residence.

From Figure 3 (Box 1) it can be noted that vaccination status acts with prenatal care and type of toilet facility to influence childhood morbidity, through OVC status. The implications are that OVCs health outcomes are not only worsened because they are more likely to have not received any vaccination (Table 3) but also because of health utilisation and environmental related problems that confront them. The pure explanatories which operate through vaccination and OVC status to influence child morbidity are age of the child, sex of the household head, the natural region and place of residence. Young and male children are less likely to have received any vaccination. Those in the South, West, North and Eastern regions and also from rural areas are also less likely to have received any vaccination compared to those in the City of Kigali and urban areas (Table 3).

Figure 3 (Box 1) shows that prenatal care operates collectively with sleeping under a bednet and place of delivery through OVC status to influence childhood morbidity. Mothers who receive skilled prenatal care are also more likely to have delivered in a health facility and their children are more likely to sleep under bed nets. This shows that OVCs health outcomes are poor not only because they have poor access to healthcare but also lack facilities that prevent illnesses such as bednets.

The pure explanatories which operate through prenatal care and OVC status are age of the child, age and sex of the household head, birth order, number of

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household members, educational status of the mother/carer and natural region. Mothers who received unskilled prenatal care are more likely to belong to households where the head is elderly (40+ years) and female, the mother/carer has no formal education or has only primary education and resides in the Southern region of the country (Table 3).

Type of toilet facility is another indicator which other intermediate factors (vaccination, sleeping under a bednet and place of delivery) operate with to influence childhood morbidity through OVC status (Figure 3, Box 1). The estimates in Table 3 and edges in Figure 3 show that health, environmental and preventive measures are collectively important determinants of childhood morbidity which can operate through OVC status. The pure explanatories which operate through type of toilet facility and OVC status are the number of household members, educational status of the mother/carer, natural region and place of residence.

[---Table 3 and Figure 3 about here---]

Conclusions

The results show a wide range of significant direct and indirect associations interacting both within and between the various sets of factors predicting poor child health outcomes among OVCs in Rwanda. The advantage of using GCM is that the factors that have no direct association with the outcome variables which are usually ignored were proven to be important, operating indirectly through other variables. The results show that OVCs have relatively a higher burden of ill-health when compared to non-OVCs. OVC status influences childhood morbidity directly and is a conduit through which other factors influence childhood morbidity. The intra-block associations show that all morbidity indicators are associated except coughing which is conditionally independent of ARI symptoms. This study also demonstrates evidence

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that some of the proximate and socio-economic factors operate both directly and indirectly through OVC status to influence childhood morbidity.

When considering the direct associations it is worth noting that healthcare utilisation, environmental hygiene and childcare factors such as prenatal care, source of drinking water and breastfeeding are important predictors of childhood morbidity. Nonetheless, vaccination status and type of toilet facility are not directly associated with childhood morbidity but they appear to have an indirect link to poor child health through OVC status. Vaccination status and type of toilet facility also act as a conduit through which a set of the socio-economic factors operate to influence poor child health through OVC status. This study presents evidence that poor healthcare utilisation, poor environmental conditions and lack of preventive measures contribute both directly and indirectly to poor health outcomes among OVCs. Socio-economic factors also aggravate the health outcomes of OVCs through a set of proximate factors and OVC status. Although previous studies had observed similar association between childhood morbidity and the proximate and socio-economic factors (Kandala et al. 2008; Kazembe et al., 2007; Kandala and Madise, 2004), this study contributed to a better understanding of the mediating effect of OVC status determining child health outcomes incorporating the interactive effect of proximate factors.

There are a few caveats in this study that are worth noting. Information on child morbidity was reported by mothers and not clinically validated. However, the reported morbidity experience is confined to the last two weeks preceding the survey. We believe that mothers are capable of understanding childhood illnesses and they are likely to provide accurate responses in the survey. On the other hand, DHS data are the only source that provides nationally representative population-level data on childhood morbidity. There is also lack of data on direct and indirect costs associated with healthcare, quality of health services delivery, and perceptions and beliefs related

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to healthcare seeking behaviour. Nonetheless, this study yielded policy relevant findings, particularly the role of direct and indirect factors which are methodologically difficult to establish otherwise.

From policy perspectives, an important finding of this study relates to the central role of OVC status in explaining poor child health outcomes. OVC status has a direct association with poor health outcomes; it also acts as a link through which many of the proximate and socio-economic factors operate to influence poor child health outcomes. The present study highlights the need to improve social and health care for OVCs, and the policy strategies that could be adopted to reduce childhood illnesses. More importantly, environmental hygiene, sanitation and preventive health measures should be given priority in programmes aimed at promoting better living conditions for OVCs.

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Table 1. Prevalence (%) of morbidity among OVCs and non-OVCs, Rwanda, 2005

Indicators	All children	OVCs	Non-OVCs	*p-value*[b]
Diarrhoea	14.2	19.1	13.7	0.007
Fever	27.1	32.2	26.5	0.027
ARI symptoms[a]	17.3	21.0	16.9	0.036
Cough	35.6	38.8	35.2	0.198
Number of children	3741	339	3402	

[a]children who had been sick with a cough accompanied by short, rapid breathing in the two weeks preceding the survey.

[b]for a chi-squared test.

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Table 2. Estimated odds ratios and confidence intervals of the direct determinants of the morbidity indicators

Explanatory variables	OR (95% CI)			
	Diarrhoea	Fever	ARI symptoms	Cough
OVC status				NS
Non-OVC	1.00	1.00	1.00	
OVC	1.48 (1.09, 2.01)	1.30 (1.06, 1.75)	1.39 (1.06, 1.85)	
Had diarrhoea	NA			
No		1.00	1.00	1.00
Yes		2.44 (1.94, 3.09)	1.71 (1.35, 2.16)	1.76 (1.39, 2.21)
Had fever		NA		
No	1.00		1.00	1.00
Yes	2.41 (1.91, 3.05)		9.73 (7.99, 11.86)	13.63 (11.37, 16.34)
Experienced ARI symptoms			NA	NS
No	1.00	1.00		
Yes	1.32 (1.01, 1.73)	2.21 (1.75, 2.79)		
Had cough			NS	NA
No	1.00	1.00		
Yes	1.62 (1.24, 2.11)	9.43 (7.64, 11.63)		
Breastfeeding		NS		NS
Still breastfeeding	1.00		1.00	
Not breastfeeding	0.49 (0.41, 0.59)		0.55 (0.46, 0.65)	
Type of prenatal care				
Unskilled care	1.00	1.00	1.00	1.00
Skilled care	0.80 (0.61, 0.99)	0.80 (0.64, 1.00)	0.78 (0.61, 0.99)	0.83 (0.70, 0.98)
Quality of source drinking water		NS	NS	NS
Poor quality	1.00			
Good quality	0.78 (0.63, 0.97)			
Age of child				
0 - 23 months	2.91 (1.90, 4.47)	1.27 (1.00, 1.73)	1.51 (1.06, 2.15)	1.91 (1.51, 2.41)
24 - 47 months	1.65 (1.15, 2.38)	0.99 (0.78, 1.31)	1.18 (0.88, 1.58)	1.40 (1.13, 1.73)
48 - 59 months	1.00	1.00	1.00	1.00
Sex of child		NS	NS	NS
Male	1.00			
Female	0.77 (0.63, 0.93)			
Birth interval	NS	NS		NS
First birth			1.00	
Less than 24 months			0.85 (0.63, 1.13)	
24 or more months			0.76 (0.60, 0.97)	
Household structure				NS
1 adult	1.86 (1.11, 3.10)	1.34 (0.91, 1.98)	1.80 (1.19, 2.64)	
2 adults	1.81 (1.14, 2.87)	1.47 (1.06, 2.04)	1.62 (1.12, 2.26)	
3 adults	2.02 (1.23, 3.33)	1.56 (1.08, 2.26)	1.66 (1.11, 2.40)	
4+ adults	1.00	1.00	1.00	
Number of household members	NS	NS	NS	
1 – 3 members				0.88 (0.71, 1.08)
4 – 6 members				0.80 (0.64, 0.98)
7+ members				1.00
Educational status of mother/carer		NS	NS	NS
No formal education	1.37 (1.09, 2.06)			
Primary	1.26 (0.86, 1.85)			
Secondary or higher	1.00			
Natural Region	NS		NS	
City of Kigali		1.00		1.00
South		1.45 (1.05, 2.00)		1.11 (0.85, 1.46)
West		1.11 (0.80, 1.54)		0.77 (0.58, 0.99)
North		1.12 (0.79, 1.59)		0.87 (0.65, 1.16)
East		1.44 (1.03, 2.02)		0.86 (0.64, 1.16)
Place of residence	NS	NS	NS	
Urban				1.00
Rural				0.80 (0.66, 0.97)

NA – not applicable; NS – not significant at p<0.05

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Table 3 Estimated odds ratios and confidence intervals of the intermediate factors and pure explanatories

	OR (95% CI)			
Explanatory variables	OVC vs. non-OVC	Skilled vs. unskilled prenatal care	At least one vaccination vs. no vaccination	Improved vs. unimproved toilet facility
Intermediate factors				
Vaccination			NA	
No vaccination	1.00			1.00
At least one vaccination	0.71 (0.56, 0.90)			1.28 (1.14, 1.40)
Sleeps under a bed net	NS		NS	
No		1.00		1.00
Yes		1.34 (1.06, 1.69)		2.12 (1.79, 2.52)
Type of prenatal care		NA		
Unskilled care	1.00		1.00	
Skilled care	0.58 (0.46, 0.73)		1.80 (0.67, 1.96)	
Place of delivery	NS			
Home		1.00	1.00	1.00
Health facility		1.69 (1.34, 2.12)	1.08 (0.91, 1.29)	1.96 (1.65, 2.33)
Toilet facility				NA
Unimproved	1.00		1.00	
Improved	0.69 (0.52, 0.91)		1.77 (1.65, 1.92)	
Pure explanatories				
Age of child	NS			NS
0 - 23 months		6.80 (4.84, 9.55)	0.25 (0.20, 0.32)	
24 - 47 months		2.19 (1.73, 2.78)	0.64 (0.53, 0.78)	
48 - 59 months		1.00	1.00	
Age of head of household			NS	NS
16-29 years	0.71 (0.52, 0.96)	1.69 (1.50, 1.95)		
30 – 39 years	0.61 (0.47, 0.80)	1.67 (0.53, 1.84)		
40+ years	1.00	1.00		
Sex of household head				
Male	1.00	1.00	1.00	1.00
Female	1.82 (1.43, 2.32)	0.46 (0.17, 0.82)	1.48 (1.25, 1.75)	0.92 (0.76, 1.11)
Birth order	NS		NS	
First		0.26 (0.18, 0.38)		1.10 (0.84, 1.43)
Second and third		0.54 (0.43, 0.70)		1.10 (0.91,1.33)
Fourth or higher		1.00		1.00
4+ adults				
Number of household members	NS		NS	
1 – 3 members		7.59 (4.95, 11.61)		0.46 (0.33, 0.64)
4 – 6 members		2.03 (1.60, 2.58)		0.77 (0.64, 0.93)
7+ members		1.00		1.00
Educational status of mother/carer			NS	
No formal education	2.24 (1.31, 3.80)	0.68 (0.47, 0.97)		0.25 (0.19, 0.34)
Primary	2.09 (1.27, 3.44)	0.72 (0.53, 0.99)		0.42 (0.33, 0.54)
Secondary or higher	1.00	1.00		1.00
Natural Region				
City of Kigali	1.00	1.00	1.00	1.00
South	1.84 (1.16, 2.92)	0.70 (0.50, 0.96)	0.60 (0.45, 0.80)	1.03 (0.76, 1.39)
West	1.55 (0.96, 2.51)	0.82 (0.58, 1.14)	0.65 (0.48, 0.88)	1.06 (0.78, 1.45)
North	1.14 (0.67, 1.91)	0.93 (0.66, 1.33)	0.72 (0.53, 0.98)	0.48 (0.34, 0.67)
East	1.77 (1.08, 2.91)	0.84 (0.59, 1.18)	0.56 (0.41, 0.77)	0.64 (0.46, 0.90)
Place of residence		NS		
Urban	1.00		1.00	1.00
Rural	0.52 (0.38, 0.70)		0.71 (0.57, 0.88)	0.78 (0.62, 0.97)

NA – not applicable; NS – not significant at p<0.05

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BLOCK 1: Socio-economic and demographic (pure explanatories)

Age of child Sex of child Birth order Birth interval Age of household head

Sex of household head Household structure Number of household members

Educational status of respondent Family religion Natural region Place of residence

BLOCK 2: Intermediate factors

Breastfeeding Vaccination Child sleeps under a bed net

Type of prenatal care Place of delivery Quality of source of drinking water

Type of toilet facility

BLOCK 3: OVC status

OVC / non-OVC

BLOCK 4: Morbidity indicators

Child morbidity (diarrhoea, fever, ARI symptoms and cough)

Figure 1. Framework for the determinants of child morbidity

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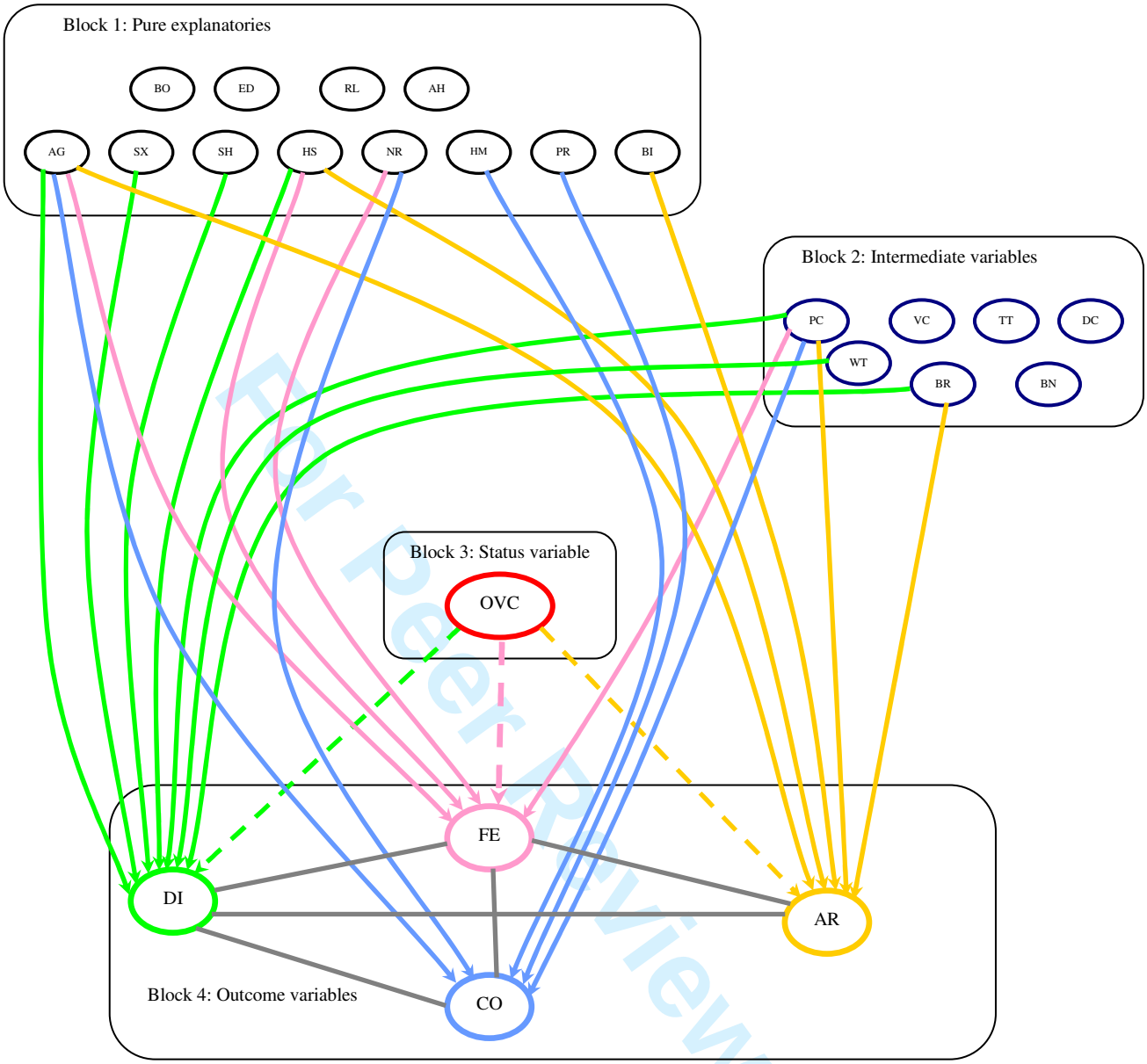

Block 4

DI – diarrhoea
FE – fever
AR – acute respiratory symptoms
CO – cough

Block 3

OVC – orphaned and vulnerable children

Block 2

BR – duration of breastfeeding
VC – child ever vaccinated
BN – child sleeps under a bed net
PC – prenatal care
DC – delivery care
WT – source of drinking water
TT – Toilet facility

Block 1

AG – age of the child
SX – sex of the child
BO – birth order
BI – birth interval
SZ – size of the child at birth
AH – age of household head
SH – sex of household head
HS – household structure
HM – number of household members
ED – education of respondent
RL – religion
NR – natural region
PR – place of residence

Figure 2. Chain graph showing the direct determinants and the inter-block association for the morbidity indicators

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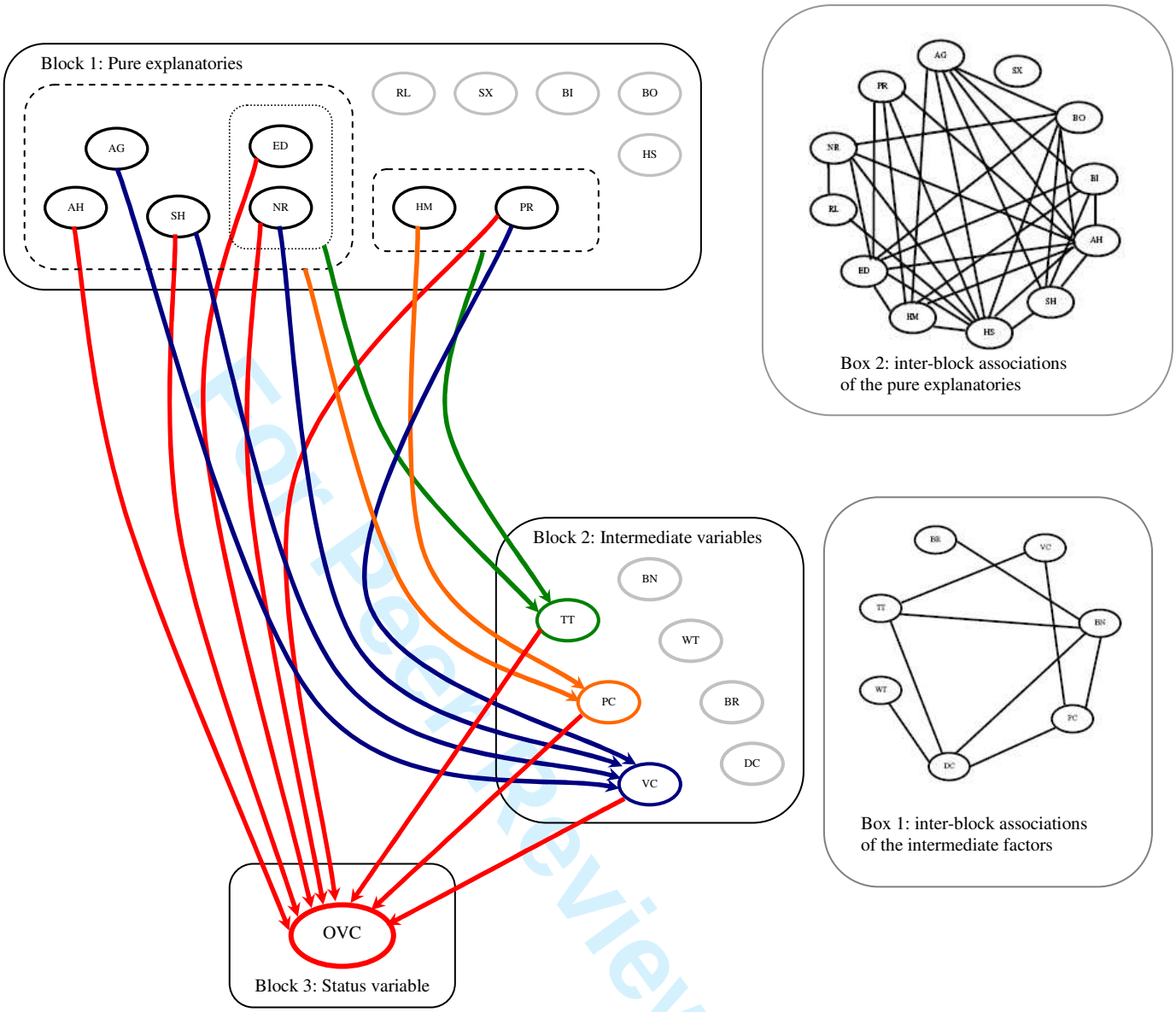

Block 3

OVC – orphaned and vulnerable children

Block 2

BR – duration of breastfeeding
VC – child ever vaccinated
BN – child sleeps under a bed net
PC – prenatal care
DC – delivery care
WT – source of drinking water
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Block 1

AG – age of the child
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Figure 3. Chain graph showing the determinants that operate through the intermediate factors and OVC status

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Manuscript ID# **AC-2009-02-0085**
Title: ***Orphanhood and vulnerability: a conduit to poor child health outcomes in Rwanda***

Revision notes
We are very grateful to the referee for providing us with the comments and feedback on our manuscript. We have managed to address all the comments raised by the referee. The word count of the revised main text (without paper title and references) is 2988. The following notes explain how we reacted to each comment.

General comments

Comment 1: If this paper offers important new insights that might be useful in helping children, it does not report them in a way that is understandable, and it does not tell us how they might be used. "The aim of this paper is to disentangle the effect of underlying complex relationship between and within the proximate and socio-economic factors that mediate poor health outcomes among children through their OVC status." This is OK, but you also need to say it in English, and then you need to say what it means. Why is it important?

Response 1: *Thank you for this comment. We have made these clear in the revision. Please note that the revised text has been shortened following the instructions from the Editor. This study addresses the direct and indirect pathways through which OVCs get exposed to morbidity risks taking into account of the interactive effect of a range of household and individual (proximate) factors (explained on Page 2, last paragraph of the introduction). The relevance of the topic, the justifications and the rationale for using graphical chain techniques to model the mediating effect of OVC status and the complex association of factors in predicting child health outcomes have been addressed properly (also please see the conclusion section).*

Comment 2: I confess that I have not fully understood the graphical chain analysis. The explanation is not all that clear. But more importantly, the paper provides me no reason for why I should spend more time and effort trying to understand it. OVC are more likely to be sick, and sick children are more likely to be sick. So what? How does your analysis help me address this? In the Introduction, you need to say why it's important to "disentangle the complex. …" in the way you propose.

Response 2: *The revision focuses more on the application and less on the methods. The methods section has been shortened, directing the reader to a few important references that provide a detailed explanation of graphical chain methods (Page 3, second paragraph). Also, please refer to Response 1.*

Comment 3: "Policy-relevant findings" (Conclusion): What are they, specifically? "The central role of OVC status in explaining poor child health outcomes." OVC status itself doesn't explain anything. It's a category we put a child in. For programmatic purposes, wouldn't it be better to target kids in categories that directly explain poor health outcomes (e.g. kids whose families are poor, or kids who don't eat enough) rather than by OVC status? The last sentence (focus on young children, identifying especially those who lack health care, those living in female and elderly headed households and those from the poorest regions of the country) – are these

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things we haven't known before? The paper needs a discussion section. Among issues that cry out for discussion.

Response 3: *The analysis clearly show that OVC status influences childhood morbidity directly and also indirectly as a conduit through which other factors influence childhood morbidity. The advantage of using GCM is that the factors that appear to have no direct association with the outcome variables which are usually ignored were proven to be important in explaining the indirect associations. The present study highlights the need to improve social and health care for OVCs, and the policy strategies that could be adopted to reduce childhood illnesses. More importantly, environmental hygiene, sanitation and preventive health measures should be given priority in programmes aimed at promoting better living conditions for OVCs. These points are stressed in the conclusion section. The conclusion section provides a brief discussion of the key policy implications. A separate discussion section is not included due to word restrictions.*

Specific comments

1. The differences in prevalence of morbidity between OVC and non-OVC are not huge.

Given the sample of 3741 children, the differences are statistically significant for all morbidity outcomes at $p<0.05$, except for cough. . Furthermore, over 20% more OVCs than non-OVCs have these three morbidities. Please refer to Table 1 and the multivariate results reported in Table 2.

2. A footnote says that there's no info on HIV status of children; this would seem to be a major point in a discussion, since many of the health outcomes could conceivably be explained by HIV status.

Yes, we agree with this comment. To avoid confusion, the footnote has been removed from the paper.

3. What does it mean that OVC status is associated with some illnesses but not with cough? Does this result make sense?

The analyses show that children suffering from cough alone are not statistically different between OVCs and non-OVCs. However, ARI symptoms are significant which include illness with a cough accompanied by short and rapid breathing.

4. What does it mean that those were breastfed were MORE likely to be sick, and how does this fit with what is known about breastfeeding?

Breastfeeding status at the time of survey refers to current status for children under-five years. We could not include the duration of breastfeeding for censoring reasons as young children would have shorter duration when compared to their older counterparts. Regarding the results, currently breastfed children are less likely to suffer from diarrhoea (which is an important result) but they are likely to be suffering from ARI symptoms. It is likely that mothers are relatively more likely to breastfeed children who suffer from illness than healthy children and hence reported as such.

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5. What does it mean that households with more adults had less illness? Better child care and income (vs. cramped living conditions and less food)?

This might reflect the care given to OVCs in households with more adults (opportunity costs rather than economic costs).

***Other specific comments*:**

Comment: Introduction - "These OVC live in deplorable conditions in households that are already poverty-stricken" – all of them?
Response: *We removed this sentence in the revision since the survey data are inadequate to comment on this observation. Also, there is no information on the tenure of OVCs in the households interviewed in the RDHS.*

Comment: The brief discussion of statistical methods should be in Methods, not the Introduction. Before we get to that, we should understand why this whole exercise is important.
Response: *Thank you for this suggestion, we understand the point. The methods are discussed only in the 'data and methods' section.*

Comment: The two-week window for child health problems is very short. You don't include malaria as an outcome?
Response: *This is standard in all the Demographic and Health Surveys conducted across less developed countries. Most retrospective surveys rely on child morbidity data from the two weeks preceding the survey. This is the case even for specific follow-up studies, example the study by Goldman et al, 1998 on the use of calendars in measuring child morbidity (International Journal of Epidemiology (Vol. 27 Issue No. 3, pp. 505-512). We believe that mothers are capable of understanding childhood illnesses and they are likely to provide accurate responses in the survey. On the other hand, DHS data are the only source that provides nationally representative population-level data on childhood morbidity. The RDHS did not ask malaria outcomes among children.*

Comment: "The conceptual framework proposed by Mosley and Chen. …" This is deep in the Data and Methods section. It's needed for us to understand where we're going, should come much earlier.
Response: *This is now discussed briefly in the introduction section (please see Page 2, last paragraph before the 'data and methods' section).*

Comment: The exclusion of nutritional measures is too bad.
Response: *Yes, we do agree with this point. Unfortunately, anthropometric data for about 56% of children were recorded missing in the individual data file for various reasons, for example the child died or was away or living elsewhere at the time of survey. Hence we could not include any nutritional measures.*

Comment: In short, tell us why the study question is important, how your findings fit in with other studies (are they new? do they contradict? do they confirm?), and how they might be used to help kids.

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Response: *Through graphical chain modelling, the study demonstrates new evidence that OVC status influences childhood morbidity directly and also a conduit through which other factors influence childhood morbidity. It concludes that the factors that have no direct association with the outcome variables which are usually ignored had indirect associations. These are elaborated in the revision. We gave careful attention to this comment while revising the manuscript.*

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