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Research Essay

Breastfeeding and
policy strategies to protect critical infrastructures in fragile states

Introduction: Breastfeeding for wealth of a fragile nation

An excerpt from the World Health Organization (WHO):

> "*Kithan is a Syrian refugee who shares a shelter with her husband, children, mother and 2 sisters in an informal tented settlement in Jib, Janine, in Lebanon's Bekaa Valley*
>
> *When she gave birth last May to her sixth child, her baby had some health complications and the doctors didn't let her feed him for several days, "I lost my milk," Khitam said, "so I fed him formula but he was getting thinner". Weeks later, as her baby's health deteriorated, Kitham carried him many kilometers on foot to seek help at the nearest health centre. "When we first saw baby Manhal, we thought he may not make it," says Fatima Al Hayek, lactation consultant with International Orthodox Christian Charities.*
>
> *Baby Manhal was immediately hospitalized and remained in hospital for 3 weeks, during which time his mother was helped to restart her milk supply, and Manhal gradually gained weight and strength. "I feel like my son was born again," says Kitam, "and I am still breastfeeding him*"
>
> Dr Francesco Branca, WHO Director of Nutrition for Health and Development (Branca & Schultink, 2016)

War affected populations disrupt economies of a system, collapses political structures, and creates masses of famine and displacement of predominantly women and children. Food insecurity impacts on a child's survivability. Since economies rely on a health nation for long-term growth of their country, investing in children's health suggests positive externalities for the future. A skilled, bright and productive population is an asset to a fragile state, which is defined as countries affected by a range of shocks[1], perpetuating famine, disease and poverty. This essay will explore breastfeeding as the most efficient and effective nutritional strategy to minimize morbidity and mortality of children in fragile states. I will discuss positive

[1] In this essay, fragile states are states with weak capacity and legitimacy (World Bank,

externalities to improved IQ scores, improved earnings and reducing the cost of negative externalities such future morbidity. These discussions aim to inform strategies for policy making via an optimization model for costs for short and long-term time horizons, which will be extended to the applicability of game theory. The focus area of breastfeeding policies will also suggest spillover benefits for policy making around children's and mothers' long-term health and the overall transfers of value to macroeconomic growth.

Population profile of children at war

Socioeconomic analysis on life-course epidemiology proposes that the most vulnerable window in a child's life is his or her first 1000 days (UNICEF, 2013). Children orphaned or abandoned under the age of two years old make up a large proportion in fragile states. In the Korean first and second civil war in, 61.3 and 65.5% of children under the age of one were displaced (Saphir, 1993). Physical stunting or anthropometric failure, affects more children in poverty than children from poorer households (UNICEF, 2014, Black et al, 2013, Kizilyildiz et al, 2006). Ninety-five percent of newborns are of Low Birth Weight (LBA) and Small Gestational Growth (SGA) infants, and pre-term categories come from the poorest countries in the world [2]. LBW is related to problems in a child's motor, cognitive and social development (as cited WHO, 2011). In conflict areas irrespective of the cause, factors such as food insecurity, poor sanitation, overcrowding and an over burdened health system contribute to limited health care services for a vulnerable population.

Breastfeeding: physiology and social contexts

The profile of newborns in fragile states demonstrate a need for best breastfeeding practices. Breastfeeding reduces the risk for acute infections such as diarrhea, pneumonia, ear infection, haemophilus influenza, meningitis and urinary tract

[2] Small gestational size (SGA) and Low birth weights (LBW), defined as below 2500g, are principal risk factors for neonatal and infant mortality in developing countries(WHO, 2011). According to WHO, sixty to eighty percent of neonatal deaths occur among LBW infants (Henderson et al, 2009.

infections (WHO, 2005). It also protects against chronic conditions in the future such as type I diabetes, ulcerative colitis, and Crohn's disease (WHO, 2005) which can be developed in later life. These illnesses require long-term investment of parental time and effort and suggests costs to the child, due to interruptions to the child's school and development. Breastfeeding delays the return of a woman's fertility and reduces the risks of post-partum hemorrhage, pre-menopausal breast cancer and ovarian cancer (Leon-Cava et al, 2002). Special circumstances are contraindicated for both child and mother in breastfeeding such as HIV Infection and if sepsis is suffered by the mother[3]. For the mother, delaying the return of a woman's fertility will help will space out the births of her children and allow her to maximize her time to care for each child. Kangaroo Care[4], a practice often coupled with breastfeeding is an alternative and cheaper way to care for LBW newborns when compared to a conventional neonatal care facility. With Kangaroo Care, even LBW infants who go undiagnosed due to lack of skilled births attendance (Amano et al, 2006) can benefit from the warmth, humidity and comfort provided by Kangaroo Care (Conde-Agudelo, Diaz-Rossello, 2017). Appropriate feeding, care and diagnoses in newborns reduce child mortality (WHO, 2011) highlights the central role of gold standard breastfeeding practices as an entirety.

Breastfeeding requires expert guidance by skilled staff in promoting practices such as Kangaroo Care. Communities that lack skilled staff employ volunteers who promote and support mothers in the peri-natal period. These interventions are typically successful due to cultural alignments between patients and service providers, in addition to the advantage of accessibility to local, specialised centers. A community-based neonatal sepsis-management intervention program in Dhanusha district in Nepal trained female community health volunteers (FCHVs) in various relevant care tasks: Weighing newborns at birth, assessing for defined signs of sepsis, and referring and assisting mothers and infants to health facilities in the community. In this study, 50,000 local volunteers were selected by a local mothers'

[3] These are such as Herpes simplex virus type 1 (HSV-1) and certain medication such psychotherapeutic drugs (WHO, 2005).

[4] Kangaroo Care is defined as skin-to-skin contact for the newborn often performed during breastfeeding (Conde-Agudelo, Diaz-Rosello, 2017) and it is not restricted to mothers.

group to address reproductive and child health issues under the Nepalese Ministry of Health in 1999 (in Amano et al, 2006). The training involved a two-by-nine day basic session and a five-day refresher training session every five years. Since these volunteers live within the region, they have good access to newborns, especially due to the design of regular and structured interval visits by the FCHVs. LBW infants or issues with infant or mother health will be referred to the nearby hospital, maximizing the chances of timely treatment (Amano et al, 2014). These volunteers provide lactation support as well under the newborn sepsis management program within their Nepalese community, as such, overcoming barriers of access and cultural differences. This Nepalese newborn sepsis management programme is successful for the continuity of care, skilled health attendance and comparably, the fact that its population live in relatively stable environments to fragile states. A programme which pays its staff would potentially aid a low-income country with a moderate range of shocks, whilst adding value in training and paying the local population. This policy strategy could add value to a local economy directly by increasing consumption, savings and the wealth of its population for their continued service to their own community. Other value added by the breastfeeding should be considered with respect to the health benefits.

Macroeconomic growth possibilities

Breastfeeding seems to be an effective and efficient method of securing a child's health. A study of seven low and middle-income countries in Southeast Asia demonstrated opportunity costs of not breast-feeding. This included improvement in cognition through higher IQ and earnings totaling to $1.6billion annually (Walter et al, 2016). The loss is greater than 0.5% of the Gross National Income for the country with the lowest exclusive breastfeeding rate (Thailand). The savings in health care are $0.3billion annually from reduced rates of diarrhea and pneumonia from early life breastfeeding. Furthermore, for Viet Nam alone, the returns of investment for every US$1 is US$2.39, a 139% increase (Walter et al, 2016). In the literature, associations between GDP and child anthropometry from 121 surveys in 26 low and middle-income countries have shown weak relationships (Volmer et al, 2014). High-income growth as well, does not guarantee the provision of service

addressing malnutrition in children (Volmer et al, 2014). These findings imply that economic growth does not necessarily lead to reduction in undernutrition, which suggests an opportunity for policy makers to 1. Reallocate resources to realize short and long-term gains and 2. Adjust expectations based on economic evidence in literature that advocate for breastfeeding. 3. As a consequence of 1 and 2, create realistic economic models to reflect short and long-term goals in terms of meaningful economic outputs with respect to costs restraints.

Challenges in breastfeeding in crises settings

Normally functioning health care systems have good health services[5], where there is equitable access to medical produces, vaccines, technologies and a well functioning information system and effective leadership and governance (Chi et al, 2016). The benefits of breastfeeding have mostly been studied in this context. However, it still remains that there has no real substitute for any child and its practice in fragile states requires a likewise system. Even though well-intentioned aid agencies supply breast-milk substitutes, due to poor water and sanitation conditions, children suffer from gastrointestinal symptoms, increasing the risk of dehydration related deaths (Branca & Schultink, 2016). Thus, when it is accessible, exclusive breastfeeding is the safest, the most economic form of feeding a newborn and an infant when costs to the households are compared with the use of breast-milk substitutes (Branca & Schultink, 2016). In fragile states, health systems are weakened and mothers do not get access to the necessary skilled workers to provide their child with this natural sustenance. The stresses of living amongst environmental shocks, increases their risk of running out of breast milk before the child is aged six months or before help is on its way (Branca & Schultink, 2016). Since infrastructures may be destroyed on a daily basis, weakened health systems may also exacerbate the child's vulnerability by its limited ability to control spreads of diseases. Poor network structures such as road access to services are also limited and adds to the burden of not only maternal and child care, but the entire system. In addition, when there is access, skilled labour in maternal and child-care are often redeployed to other areas of a humanitarian site

[5] It is assumed that hospitals practice evidence-based care.

to aid with incoming urgencies (Branca & Schultink, 2016). The context of health care system in fragile states and current solutions warrant for innovative policies protect, promote and support breastfeeding in these situations. Furthermore, long-term gains in economically meaningful outputs cannot be realized as they have been in less-fragile and non-fragile states.

Lessons from Jordon, albeit not a fragile state, demonstrates successful policy implementation, suggesting externalities in protecting women and children in general. Infant and young child feeding programme have established in Syrian refugee camps to create mother-baby friendly spaces in caravans and promoted them as safe havens for breastfeeding, where privacy and support were provided for all pregnant women and mothers of children under five (Chi et al, 2014). Daily education sessions were held in the caravan on the importance of breastfeeding, which foods to give to children aged 6 to 2 years and how to feed a young child who is ill. In Za'tari campes, more than 15 000 mothers have benefited from caravan and tent counseling sessions between December 2012 and May 2014. Similar examples where UNICEF and its partners have established such programs have existed in Croatia, Serbia and the former Yugoslav Republic of Macedonia (Chi et al, 2014). These spaces also provide security to patients, reducing the risk of sexual violence and providing adequate support for survival (Chi et al, 2014). In addition, these safe spaces can potentially protect women from sexual violence, provide education and support for women who are often forced to provide sex in exchange for good (Sapir, 1993). Health services for lactating women allow issues of sexually transmitted infections, unwanted pregnancies and terminations to be addressed (Sapir, 1993). These examples demonstrate functioning health camps which be limited in a model for a fragile state to establish a long-term breast-feeding programme. However, it is important to note that positive externalities related to breastfeeding suggest trade offs policy makers must carefully consider during investment decisions related to maternal and child health. Given that fragile states may not initially be able to adopt those program seen in Jordon or Nepal, it is then imperative to discuss how such critical infrastructures can be protected, accounting for shocks and threats to the health care system and beyond.

Minimizing costs, maximizing outcome: A strategic policy

"The whole is greater than the sum of its parts"

Aristotle

Critical infrastructures are vulnerable in the humanitarian operations. The National strategy for Homeland Security identifies thirteen infrastructure sections[6] critical to the United States, which are defined as physical systems that connect components of an economy, and represents a huge investment in any nation's wealth (in Brown & Carlyle, 2005). Minor disruptions, random or deliberate can severely degrade a system's performance due to spillover effects on its codependent systems (Brown & Carlyle, 2005). Any infrastructure can be vulnerable in a fragile state and a thorough assessment, can make policy more informed in the allocation of scarce resources.

This paper proposes to explore the same technique from the point of view of service policy planning in fragile states. Adapted from the Brown and Carlyle (2009) paper, Table 1 demonstrates a vulnerability analysis with an economic policy measure for a health service devoted to maternal and child health.

Table 1: Vulnerability Analysis adapted for Health Systems

Criteria	**Policy measures**
Criticality: How essential is the asset?	IQ, Future earnings, GDP and HDI
Vulnerability: How susceptible is the asset to surveillance or attack	Probability of direct or indirect attack (physical or cyber)
Reconstructability: How hard will it be to recover from inflicted damage, considering time, special repair equipment, and manpower required to restore normal operation	DALY[7], QALY[8], GDP and HDI[9]
Threat: How probable is an attack on this asset?	GDP and HDI

[6] Agriculture, Water, Emergency Services, Defence Industrial Base, Energy, Banking and Finance, Food and Public Health, Government, Information and Telecommunications, Transportation, Chemical Industry, Postal and Shipping (Department of Homeland Security in Brown et al, 2005)

[7] DALY : Disability adjusted life-years

[8] QALY : Quality adjusted life-years

[9] HDI : Human Development Index

The protection of humanitarian operations, and indeed health care services in fragile states includes an assessment of the geo-political region. Authors of the same paper discussed the potential of gaining up to 100% insight on the opponents, claiming that public resources alone would permit this. Gaining such opponent insight and informing own strategies is the practice of game theory and in the setting of man-made shocks such as war, these discussions become highly relevant in the protection of critical and vulnerable infrastructure. It is important to note however, the scope of this essay is to present ideas and tools that policy makers can use with evidence-guided models and empirical research. As such, Brown & Carlyle's (2009) attacker-defender model of cost minimization (for the defender) will be adapted, and the empirical work done for Grim Trigger strategy will also be discussed as potential tools to inform policy.

Brown and Carlyle's (2009 p105.) "system user" model is used to optimize the infrastructure system with a shared objective function between the "attacker" who plans to maximize the cost to the "defender", who plans to minimize it. The linear model denoted by cy assumes that the costs multiplied by infrastructure will escalate linearly.

We begin with a linear program model of several variables:

$$\boldsymbol{mix\ max}\ c_1 y_1 + c_2 y_2 + c_3 y_3 + c_4 y_4$$

$$s.t. \mathrm{A}\boldsymbol{y_1} + \boldsymbol{I_1 y_2} + \boldsymbol{I_3\ y_3} + \boldsymbol{I_4\ y_4} = \mathbf{b}$$

$$c_{1-4}$$

$$\boldsymbol{y} \in Y, \boldsymbol{A}, \boldsymbol{I} \in A$$

y represents the limits of a system, e.g. gains or losses IQ, Future earnings, GDP, QALY, DALY or HDI increments, number of patients or number of skilled staff. Therefore Y represents constraints on a system's capacity.

A or **I** is derived from public and private insight to measure the probability of gaining each input **y**. c_{1-4} corresponds to costs of the losses or gains in the above economic outputs and can contain more or less coefficients. **b** represents a vector of

supply and demands.

It can be assumed that the system user is operating at a chosen random point, for example, at 90% of their efficiency-frontier. A short and long-term model is proposed which will allow expectations of policy in their resource allocation. It is now important to note that transparency and accountability will be strengths of these models.

A note on peacekeeping: Lessons from a real Grim Trigger strategy

Grim Trigger strategy is a type of repeated games involving two players with two different actions, for example: Shoot or Miss. The strategy is adopted when a sequence of mutually conforming actions are deviated by one player, resulting in both players playing this action at the subsequent games thereafter. The theory helps to derive pay offs over an infinite time horizon. Pay offs in the future games are discounted to its present value, by value $\boldsymbol{\delta}$**,** which represents how much players care about their pay offs in the future. It is useful to conclude that the model used has a symmetric payoff between attacker and defender, and has empirical groundings in the relationship between German soldiers and their allies during the World War I (Harrington et al, 2015). The symmetric payoff structure implies four results: 1. Subprime Nash equilibrium in repeated games achieve the highest pay off when there is no deviations in strategies. 2. The Pay off is highest when cooperating with peace after even after the one deviation. 3. The pay off for cooperating with peace (Miss, Miss) is superior to the opposite (Kill, Kill). Table 3-5 (Appendix A) demonstrates the four points mentioned. The mathematical explanations in Appendix A demonstrate that by deducing $\boldsymbol{\delta}$, the minimum discount factor required for both players to cooperate can be realised, which makes this value fundamental to the discourse in peacekeeping and the protection of vulnerable systems.

Combining game theory in policy

The models provided in this essay have its strengths and limitations. Typically no single organisation has sufficient resources to effectively manager a disaster (Bui et

al, 2001). Aid agencies continue to provide gold standard health care, derived from developed states without adequate infrastructure. The assumption of a linear relationship between cost and capital may require adjustment depending on the nature of the output being measured. However, these models may be applicable to interdependent systems of health such as supply-chain, cyber-security, waste and sanitation management. Furthermore, whilst "defending" may be a key component to their peacekeeping processes, a discussion on the Grim Trigger strategy theory may provide insight into gaining a desirable cooperation between attacker and defender, a discourse pertinent to protecting critical infrastructures. These tools of economics are available for policy makers to make top down decisions that affect a nation's ability to rebuild itself, starting from securing infrastructure for the health of its most vulnerable.

Conclusion

Breastfeeding practices suggests an effective means to ensure a healthy and productive population. A vulnerability assessment allows policy makers to realize optimal allocation of resources in critical infrastructure when it is measured with meaningful outputs. An optimizing objective function reflects this relationship by quantifying the costs in gains of meaningful economic outputs such as IQ, future earnings, GDP and HDI in the short and long-term. An extension of this idea is the study of cooperation and coordination mechanisms between multi-systems environment containing co-dependence sub-systems such information networks, supply chain and power and water source to external shocks to a fragile state. The identification and manipulation for $\boldsymbol{\delta}$ can potentially guide policies in maximizing pay offs of all agents within a system, whilst protecting critical infrastructures that support fragile states for the long term.

Appendix A

The Grim Trigger strategy model begins with several assumptions. The pay offs to the defender-attacker model is used with the pay offs modeled by a historical and empirical example of the World War I from Harrington et al (2015) is illustrated in Table 2.

Table 2: Defender-attacker model (Harrington et al, 2015)[10]

		Defender	
Attacker		Kill	Miss
	Kill	2,2	6,0
	Miss	0,6	4,4

Table 3: Pay off for consistently killing

	T[11] = 1	T= 2	T = 3	T = 4
Attacker	kill = 2	kill = 2	kill = 2	kill = 2
Defender	kill = 2	kill = 2	kill = 2	kill = 2

Table 4: Pay off for consistency missing

	T = 1	T= 2	T = 3	T = 4
Attacker	miss = 4	miss = 4	miss = 4	miss = 4
Defender	miss = 4	miss = 4	miss = 4	miss = 4

Table 5: Pay off for deviating : Grim Trigger strategy for peace

	T = 1	T= 2	T = 3	T = 4
Attacker	kill = 2	kill = 6	miss = 4	miss = 4
Defender	kill = 2	miss = 0	miss = 4	miss =4

Table 6: Pay off for deviating: Grim Trigger strategy for KILL

	T = 1	T= 2	T = 3	T = 4
Attacker	kill = 2	kill = 6	kill = 2	kill = 2
Defender	kill = 2	miss = 0	kill = 2	kill = 2

More pressing is the discussion on cooperation. Since the games have symmetric pay offs, upon establishing the infinite pay offs by the attacker and defender, we

[10] From Harrington et al (2015) and is based on the empirical and historical example of World War I.
[11] T = time period up to 4, but is assumed to go to infinity.

illustrate our four results below.

Deviating reduces pay offs as we compare Table 4 and 5:

$$\frac{\mathbf{2}}{\mathbf{1}-\boldsymbol{\delta}} > \boldsymbol{\delta}\frac{\mathbf{2}}{\mathbf{1}-\boldsymbol{\delta}}$$

Even with Grim Trigger strategy, repeated games in "miss" has a higher pay offs than kill (Table 5 and 6)

$$\frac{\mathbf{4}}{\mathbf{1}-\boldsymbol{\delta}} > \mathbf{6} + \boldsymbol{\delta}\frac{\mathbf{2}}{\mathbf{1}-\boldsymbol{\delta}}$$

$$[\boldsymbol{formula}\ \mathbf{1}]$$

Following Solving for $\delta\ from\ \boldsymbol{formula}\ \mathbf{1}$**:**

$$(\mathbf{1}-\boldsymbol{\delta}) \times \frac{\mathbf{4}}{\mathbf{1}-\boldsymbol{\delta}} \geq (\mathbf{1}-\boldsymbol{\delta}) \times \boldsymbol{\delta}\left[\mathbf{6} + \boldsymbol{\delta}\left(\frac{\mathbf{2}}{\mathbf{1}-\boldsymbol{\delta}}\right)\right]$$

$$\mathbf{4} \geq (\mathbf{1}-\boldsymbol{\delta})\mathbf{6} + \boldsymbol{\delta}\mathbf{2} \Rightarrow \mathbf{4}\boldsymbol{\delta} \geq \mathbf{2} \Rightarrow \boldsymbol{\delta} \geq \frac{\mathbf{1}}{\mathbf{2}}$$

We obtain the coefficient $\boldsymbol{\delta}$ for cooperation as 0.5.

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