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Contextualizing Stunted Child Growth and Development within a Broader Framework of Demographic Transition and Epidemiologic Transition*

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ABSTRACT

This study proposes a broader framework of demographic and epidemiologic transition for contextualizing changes in stunted child growth and development. A complete model test using random effects modeling incorporating the influences of three economic forces, the proximate macro-economic force, time-specific effect, and region-specific effect, strongly supports the efficacy of the proposed framework for explaining the national stunted growth rates in less-developed countries. Policy implications are discussed.

Key Words: demographic transition, epidemiologic transition, stunted child growth and development

I. Introduction

In 2012, the World Health Organization (WHO) set a global target to reduce childhood stunting by 40% by 2025; in other words, to decrease the number of stunted children under age five from 171 million in 2010 to approximately 102 million in 2025 (de Onis et al., 2013). Although there are rationales provided for

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setting the goal and for actions to be proposed, the actual causes of stunting remain unclear. Recent efforts to estimate the distribution of children's anthropometric status indicated that more than 171 million children aged under 5 years in 2010 were mildly, moderately, or severely stunted; moreover, developing countries appeared to have less than a 5% chance of meeting the Millennium Development Goal (MDG 1) by 2015 (Stevens et al., 2012). Several interpretations for the worsening anthropometric status in sub-Saharan Africa, including macroeconomic shocks, structural adjustment, and trade policy reforms, were believed to be the main causal factors, but there is a lack of empirical evidence supporting these claims. Other possible contextual factors include political economy, health and health care systems, education, society and culture, agriculture and food systems, as well as water, sanitation, and the environment (Stewart et al., 2013); however, no study has tested the efficacy of these factors for guiding subsequent programs and policy interventions, or for achieving transdisciplinary solutions.

De Garine and Bengoa (2009) urged the linking of the nutrition transition and behavioral sciences to explain the causes of malnutrition heuristically to develop a broader framework approach for addressing the child stunting problem. This study contributes to exploring an evidence-based broader framework not addressed in the literature. The following section first examines the insufficiencies of current perspectives on child stunting, and then proposes a demographic transition thesis to explain undernutrition and stunted growth. The thesis delineates a broader framework of the demographic and epidemiologic transition to systematically examine trends in stunting reduction. The main purpose of this research is to provide scientific evidence for documenting the contextual factors for evidence-based decision-making in nutrition transition and stunting reduction (Rivera, 2009).

II. Review of the current perspectives

A review of current perspectives of undernutrition and healthy growth indicate an over-emphasis on gross national income (GNI) as the criterion for classifying national performance (Stevens et al., 2012; Marriott et al., 2012; Black et al., 2013), as well as an under-emphasis on other crucial contextual factors for tracing a nation's health position during the nutrition transition process. Given that the underlying causes of stunted growth can be traced back to the interlinkage among demographic, epidemiologic, and nutrition transition (Shrimpton and Rokx, 2012), it is important to identify the crucial contextual conditions under which nutrition transition for reducing stunted growth contribute to a classification of countries in terms of contextual factors rather than GNI alone. Moreover, previous studies on the social determinants of health (SDH), with a specific focus on health impacts of income inequality, have yielded controversial and inadequate support of a relationship between income inequality and population health (de Poel et al., 2008; Reinbold, 2011). This has raised questions about the structural determinants and constraints of public health. Accordingly, previous research on economic inequality and child stunting can be reexamined under a complete model of the broader framework. Furthermore, a structure-agency approach to health can be linked to the communities' efforts to build momentum for undernutrition reduction (de Garine and Bengoa, 2009), and it can be more thoughtfully addressed under the demographic transition thesis.

Current perspectives have concentrated on the role of maternal education in affecting child stunting and undernutrition (Lockwood and Collier, 1988; Semba et al., 2008; Shroff et al., 2009; Postel-Vinay and Sahn, 2010; Jiang et al., 2015), and empirical evidence has supported the impact of foreign direct investment (FDI) on food security and malnutrition (Mihalache-O'keef and Li, 2011). For those factors to be included as contributing to the improvement of nutritional status of populations, the influence of either FDI or maternal education must be shown to hold under a broader and more comprehensive framework.

Previous research has failed to consider the interacting effect of infection and malnutrition (Dewey and Mayers, 2011) as well as the critical role of epidemiologic transition in reducing national stunting. A demographic transition thesis combining the effect of demographic transition on favorable conditions of population health and subsequent epidemiologic transition can address this gap in the approach toward stunted growth and development. Finally, previous endeavors have emphasized micro and immediate strategic practices in proposing resolutions to reduce malnutrition and stunted child growth, while failing to consider a broader and more macro framework under which child stunting trends can be systematically examined. Previous studies have reported on the limitations of current indicators of micronutrient status, and observed no effect of maternal multimicronutrient supplementation on child growth (Allen, 2009; Wang et al., 2012); thus, a broader framework to subsume and guide the interventions and action toward reducing undernutrition could improve a more macro framework (de Garine and Bengoa, 2009; Rivera, 2009) and the macro-micro link for addressing health problems.

III. Demographic transition, epidemiologic transition, and child stunting

This study aims to propose a conceptual framework contextualizing stunted child growth and development within a broader framework of demographic and epidemiologic transition. The contextual factors of malnutrition and stunting reduction have been widely examined (UNICEF, 1990; Stewart et al., 2013). These contextual factors either cover economic structure or political and ideological superstructures (UNICEF, 1990), or further extend to political economy, health and health, care systems, education, society and culture, agriculture and food systems, as well as water, sanitation, and the environment in a WHO framework (cited in Stewart et al., 2013). These contextual factors provide profound contexts for proposing and implementing adequate programs and policies. One of the main problems in determining whether these contextual factors influence malnutrition or stunting reduction lies in a lack of empirical evidence to document and determine the importance of factors which can actually promote healthy growth and development. Because former programs and policies have typically focused on the more proximal causal factors, such as household and family factors, a broader evidence-based framework for guiding policy and program planning can substantiate a well-considered transdisciplinary action leading to the reconsideration of more proximal factors. Ultimately, the approach of a broader framework is conducive to leveraging positive contextual conditions for malnutrition and stunting reduction, or at least to creatively circumvent barriers to change efforts. Moreover, the aforementioned contextual factors can be critically examined within this broader framework to confirm their unique contribution to promoting healthy growth and development.

This broader framework of demographic and epidemiologic transition has its origin in the most recent developments of applying the demographic transition thesis to the shaping of modern society (Dyson, 2001), economic transition for sustained growth (Galor, 2005), democratic transition (Dyson, 2012), human development (Chen, 2013), and epidemiologic transition (Chen, 2014). For the approach of a demographic transition thesis on stunted child growth and development, the systematic correlation between demographic and epidemiologic transition has been closely linked and critically examined. The role of favorable conditions of population health—conceptualized as the prevalence of health manpower, health innovations, healthy living, and health knowledge—accompanying the demographic transition process has been considered to be a crucial contextual determinant of epidemiologic transition. This can be illustrated by using a measure of demographic transition and an index of favorable conditions of population health, as applied in population health efforts and effectiveness evaluation (PHEEE). The two contextual determinants of epidemiological transition can be cross-tabulated to report the mean percentage of epidemiological transition outcomes in less-developed countries. Table 1 presents the trends in epidemiologic transition. The communicable diseases-to-injuries transition (calculated as the mean percentage of injuries to communicable

Table 1: Mean percentage of epidemiologic transition outcomes in 2008 following various levels of demographic transition (DT) and favorable conditions of population health, as applied in population health efforts and effectiveness evaluation (PHEEE)

	Low PHEEE	Medium PHEEE	High PHEEE
Low DT	Communicable disease to injury transition: **16.1%** Communicable disease to noncommunicable disease transition: **119.6%**	Communicable disease to injury transition: **48.2%** Communicable disease to noncommunicable disease transition: **192.5%**	
Medium DT		Communicable disease to injury transition: **59.3%** Communicable disease to noncommunicable disease transition: **408%**	Communicable disease to injury transition: **53.2%** Communicable disease to noncommunicable disease transition: **397%**
High DT		Communicable disease to injury transition: **27.5%** Communicable disease to noncommunicable disease transition: **284%**	Communicable disease to injury transition: **86.8%** Communicable disease to noncommunicable disease transition: **732%**

diseases) for the countries involved in this study respectively ranged from 16.1%, to 59.3%, and 86.8% in low, medium, and high demographic transition and PHEEE levels, agreeing with the projection that injuries will be comparable to communicable diseases as a source of ill health by 2020 (WHO, 2012).

A close examination of the transition from communicable diseases to noncommunicable diseases (calculated as the mean percentage of noncommunicable to communicable diseases) also reveals a substantial increase in demographic transition and PHEEE levels from 119.6% (low), to 408% (medium), and 732% (high), which is in agreement with the most recent projection that noncommunicable diseases will account for 7 of 10 deaths in the developing world by 2020 (WHO, 2012).

The world position of epidemiologic transition for various less-developed countries can also be illustrated by this cross-tabulation (table not presented). As an extension, the classification of countries according to the level of demographic and epidemiologic transition can provide a more heuristic method for determining the level of malnutrition and child stunting not accountable by GNI alone.

Between the two epidemiologic transitions, transition from communicable to noncommunicable diseases (rather than communicable diseases to injuries transition) is the most crucial for healthy growth and development (Shrimpton and Rokx, 2012; Zhai et al., 2009). Because the later stage of nutrition transition is typically characterized by high rates of diet-related noncommunicable diseases, aside from the impact of demographic transition, transition from communicable to noncommunicable diseases is expected to play a pivotal role in directly affecting stunted child growth and development.

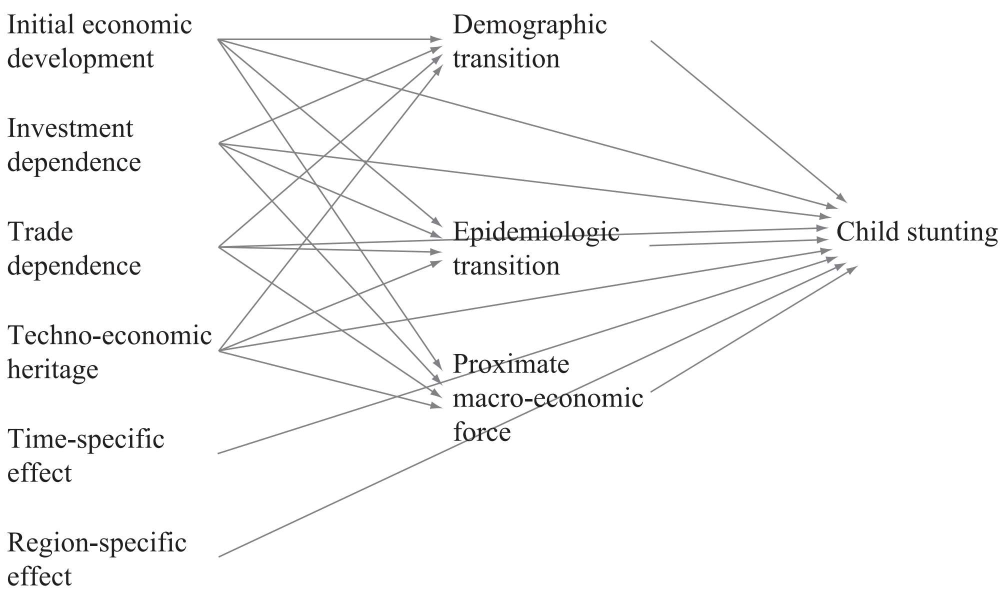
The complex process of demographic transition incorporates a global fertility transition, societal forms transition, and global communication and diffusion for cultural transition (Dyson, 2001; Reher, 2004; 2011; Chen, 2013). These transitions have implications for a later nutrition transition. The demographic transition thesis on child stunting hinges on the active roles of women during the fertility transition. A reduction in fertility which promotes the status of women through equitable education has been cited in explaining the total reduction in undernutrition (Lockwood and Collier, 1988). The role of caregivers as played by women is more receptive to innovations and knowledge of food and nutrition, and knowledge of adequate complementary feeding is a crucial pillar to support healthy growth and development. Accordingly, under a broader framework of the demographic and epidemiologic transition, researchers can determine which programs and policies are effective and why.

De Garine and Bengoa (2009) linked the nutrition transition with behavioral sciences to consider the critical roles of ideation, values, and beliefs in affecting food-consumption behaviors. Because deeply held beliefs about food-related behaviors are heavily influenced by a primary caregiver's social network, efforts to promote healthy eating habits in tandem with the fertility transition are primarily related to the communication and diffusion of knowledge, information, and innovations for caregivers to understand and respond through appropriate nutrition behavior (Hauser et al., 2011).

Accompanying the societal transition from a traditional society, to a transitional, and a modern one, the considerable momentum for refocusing investment in programs and research on improving maternal and child nutrition has resulted primarily from the development of a civil society with change agents and human agency (Gillespie et al., 2013). Relatedly, the innovative conceptual framework of social quality theory, which focuses on social cohesion, social inclusion, social empowerment, and socioeconomic security, can facilitate a structure-agency understanding of the SDH (Ward et al., 2011). The structure-agency nature of demographic transition has been adequately addressed in recent research (Chen, 2014). Demographic transition constitutes one of the main forces inducing economic transition for sustained growth, democratic development, and human development (Galor, 2005; Dyson, 2012; Chen, 2013). Consequently, the positive contexts of sustained economic growth, democratic development, and human development as fostered by demographic transition lead to the emergence of a civil society, where efforts are directed toward improving human health situations. Thus, a structure-agency linkage characterizes the unique contribution of demographic transition in mobilizing human efforts to create favorable conditions of population health, the accompanying epidemiologic transition, and subsequent nutrition transition and stunting reduction (Chen, 2014; London and Schneider, 2012).

Contextualizing child stunting and undernutrition under a broader framework of the demographic and epidemiologic transition by incorporating the efforts of framing, generating, and communicating knowledge and evidence can create and sustain the momentum for undernutrition reduction by raising public awareness of nutrition. A robust evidence-based broader framework could be an effective driver for creating and sustaining national and subnational attention and instigating change to address the problem of undernutrition.

In this proposed contextualization thesis, a full conceptual framework for explaining child stunting incorporating the influences of demographic transition, epidemiologic transition, and three preceding economic forces, the proximate macroeconomic force, time-specific effect, and region-specific effect can be sketched as follows:[1]



1 The explanatory variables of the proposed framework have strong theoretical bases and have been documented in the sociological literature. Because the causality comes from theory, the causality does not constitute a problem for the proposed framework, nor can factor analysis alone determine if common factors result in common results.

IV. Modeling demographic transition

Demographic transition refers to a transition from high infant mortality and fertility to low infant mortality and fertility, which also marks the transition of a society from a traditional, through a transitional, to a modern one. These transitions are combined with global communication and the diffusion of information and ideas regarding innovations and cultural values. An inquiry into the entire demographic transition process must consider both macro structural and cultural aspects to capture the full scheme. Because macro structural and cultural aspects consist of both original and derived elements, it is the original rather than derived elements that forge the essence of the demographic transition. The most remarkable characteristics of the demographic transition encompass both a structural and a cultural component, and prior work has examined this cultural factor for a full understanding of the fertility transition (Carlsson, 1966; Cleland and Wilson, 1987; Kirk, 1996; Lesthaeghe and Meekers, 1986; Pollak and Watkins, 1993; Caldwell, 1993; 2001; Bongaarts and Watkins, 1996; Reher, 2004; 2011).

The structural component incorporates both an original element (infant mortality and fertility) and a derived element (age structure, youth dependency, aggregate population growth, labor force growth, working-age population growth, child population, and adult population). The cultural component indicates the role of global communication and diffusion of information and ideas regarding innovations and cultural values (Carlsson, 1966; Bongaarts and Watkins, 1996). This component encompasses the original element of visible carriers of communication tools (telephone mainlines and internet hosts) as material social facts, and additional derived elements (developmental idealism and individualism) as nonmaterial social facts (Durkheim, 1964).

Global communication and diffusion of information and ideas for development have several implications. First, early diffusion research has traditionally centered on the effects of innovation diffusion on the changes of attitudes and subsequent behavior, whereas relatively recent efforts have focused on the effects of diffusing capital, institutions, organizations, and liberalism on development (Frank, 1971). The implicit diffusion effect implies the transition of a relatively closed society to a relatively open one. Second, the communication and diffusion of information and ideas regarding innovations and cultural values of the human transition process eventually foster economic, social, and health development (Reher, 2004; 2011).

Most previous studies have focused solely on the derived structural elements of demographic transition, such as examining the effects of population growth, change in child or adult population, and labor force growth on economic development (e.g., Crenshaw et al., 1997). Some studies have used only one original element, such as mortality decline (Kalemli-Ozcan, 2002), but have not investigated the combined effects of the original structural and cultural elements.

Previous research efforts using fertility measure in determining its effects on social economic development have often failed to reveal a significant effect of fertility decline alone, although a simple fertility decline has been found to affect government expenditures on old age pensions, health expenditures, and human capital expenditures. The discrepant findings regarding the simple fertility decline effect can be reexamined by taking various indices of a global fertility and cultural transition into account (Chen, 2013).

The latest re-conceptualization of demographic transition as a global fertility and cultural transition enriches the theorizing and index construction measurement of demographic transition (Chen, 2013). The indices for modeling demographic transition must combine indicators from both original structural and cultural elements. The indicators of total fertility, infant mortality, telephone mainlines, and internet hosts can be transformed into standardized Z scores. Following the reconceptualization of demographic transition as a global fertility and cultural transition, empirically represented by the decline of infant mortality and fertility (negative indicators) and the rise of global communication and diffusion of information and ideas (positive indicators), these Z scores can be used to construct various indices (see table below). The indices embody the rise of global communication and diffusion of information (positive indicator) and the decline of fertility and infant

Construction of indices for modeling demographic transition

1. gFACT4: Zlntelephone mainlines + Zlninternet hosts − Ztotal fertility rate − Zinfant mortality rate
2. gFACT3: Zlntelephone mainlines + Zlninternet hosts − Ztotal fertility rate
3. gFACT2-TELTFR: Zlntelephone mainlines − Ztotal fertility rate
4. gFACT2-NETTFR: Zlninternet hosts − Ztotal fertility rate
5. gFACT2-TELIMR: Zlntelephone mainlines − Zinfant mortality rate
6. gFACT2-NETIMR: Zlninternet hosts − Zinfant mortality rate

Notes: gFACT: global fertility and cultural transition; data for total fertility rate and infant mortality rate were obtained from the *Demographic Yearbook*, 1995, 2000 (United Nations, 1995-2000); data for telephone mainlines and Internet hosts are from the *World Development Indicators* for 1995 and 2000 (The World Bank, 1995-2000) and have been logged to correct for skewness.

mortality (negative indicator). A factor analysis of these four indicators yields the factor loadings for total fertility (−0.947), infant mortality (−0.957), telephone mainlines (0.981), and Internet service providers (0.961), all of which load onto one factor with a high degree of variance explained (92.51%). The intercorrelations among the constructed indices were high, as expected, ranging from 0.992 to 0.914. They correlated 0.850 to 0.826 with median age, which is an alternative measure of demographic transition as proposed by Dyson (2012).

V. Methods to approach the broader framework

A holistic understanding of the broader framework accounting for differences in national stunting rates must consider the possible influences of the three economic forces as distal structural forces, the proximate macro-economic force, as well as both time- and region-specific effects to reduce potential unobserved heterogeneity bias. The three economic forces are the distal structural forces for subsequent development. Both initial economic development and techno-economic heritage represent the intranational momentum of the preindustrial and industrial society, whereas investment and trade dependencies capture the probable driver of international forces in any country (Kentor, 1998; Lenski and Lenski, 1982; Shannon, 1989).[2]

The data of the preceding economic forces were measured as follows: Proximate economic force was measured as GDP per capita in 1995 and 2000; the data were obtained from *World Development Indicators* (The World Bank, 1995-2000). Initial economic development was measured as real GDP per capita in 1980; the data were obtained from Summers and Heston (1984). Investment dependence was measured as transnational corporate penetration in 1967, with data obtained from Bornschier and Chase-Dunn (1985); this measure must be interpreted inversely because of the denominator effect (see Firebaugh, 1992). Trade dependence was measured as trade as a percentage of GNP in 1965; the data were obtained from Taylor and Jodice (1983). Techno-economic heritage was measured as agricultural density in 1960; the data were obtained from Taylor and Hudson (1979).

A preliminary analysis of a Lagrange Multiplier test (LM test) and a Hausman test for evaluating the effects of the measures of demographic transition (i.e., gFACT4 or median age) on national stunting rates for both sexes (while controlling

2 The cultural background of the modernization theory, as well as the structural backgrounds of dependency/world system theories and the ecological-evolutionary theory have been linked to demographic transition theoretically, and supported empirically by data. The tables of the findings are available from the author.

the effects of GDP per capita and the measure of epidemiologic transition) was conducted. The LM test shows a test value of 22.3 ($p < 0.001$) for gFACT4 and 19.63 ($p < 0.001$) for median age, demonstrating that the choice of random effect modeling is better than the least-squares method. The Hausman test also yields similarly nonsignificant results (0.84, $p = 0.8405$ for gFACT4; 0.99, $p = 0.8030$ for median age).[3] In the following analysis, random effect modeling is employed to assess the impact of the demographic and epidemiologic transition on national stunting rates for both sexes. The time-invariant property of the distal structural forces renders fixed effects modeling inappropriate for the analysis. The theory-deduced guiding research forcefully justifies the inclusion of distal structural forces in the modeling process for a full model test.

To test the proposed demographic transition thesis, it is crucial to first model demographic transition. The most recent studies to model demographic transition have employed either median age or indices of a global fertility and cultural transition to represent demographic transition (Dyson, 2012; Chen, 2013). The effects of various indices of a global fertility and cultural transition and the median ages can be compared to determine the relative empirical efficacy.

Given that the cause-of-death patterns represent the proportion of all deaths attributable to each of these cause groups, the measure of epidemiological transition can be determined by calculating the log ratios of noncommunicable diseases (Group 2 in the "Global Burden of Disease" (WHO, 1990)) relative to communicable diseases (Group 1); in other words, the log ratio of the proportion of non-communicable diseases to that of communicable diseases [Ln(p2/p1)] denotes the communicable diseases to non-communicable diseases transition. Data of the cause groups were obtained from statistics published by the WHO for 2000 and 2008 (WHO, 2000–2013).

The dependent variables are the national stunting rates for males, females, and both sexes. National stunting rate can be defined as the percentage of children with height-for-age below minus two standard deviations from the median of the WHO Child Growth Standards. Data on national stunting rates from 2000 to 2005 and 2008 to 2013 were obtained from the WHO (WHO, 2000–2013). The available data of national stunting rates for each country are quite different, as not all countries provided annual data on that measure. The contextualization thesis of

3 Because of the strong theoretical bases of the proposed framework, plus the high quality measures of various indices, random effect modeling was used for the data analysis. The random effect modeling also has its own advantage in taking time-specific effect as a control, which is not possible using structural equation modeling, a very popular tool for analyzing psychological measurement models.

national stunting examines the impact of demographic transition and epidemiologic transition including two effects: the synchronization effect and the time-lag effect. For the synchronization effect, and to maximize the difference between the two periods, most of the national stunting rates were collected and clustered around the target years of 2000 and 2008 respectively as specified by the model. This selection of the data is appropriate given that the measures of epidemiologic transition were collected for 2000 and 2008. The available data of proxy years for the two periods were collected if the data for the target year were missing (e.g., data of 2001 or 2003 for 2000 and 2009 or 2010 for 2008). The time-lag effect extends the impact of epidemiologic transition up to five years, and thus the stunting rates were collected for the target years of 2005 and 2013 respectively.

The time specification for measures of demographic transition, epidemiologic transition, and national stunting can be stated as follows: (a) for measures of demographic transition: 1995 (t1), 2000 (t2); (b) for measures of epidemiologic transition: 2000 (t1), 2008 (t2); (c) for national stunting rate: 2000 (t1), 2008 (t2) for the synchronization effect and 2005 (t1), 2013 (t2) for the time-lag effect. For a systematic approach to the synchronization effect and the time-lag effect, due to the data availability, I divided the measures into two periods to grasp more thoroughly the hypothesized causality and the proximate effects of demographic transition and epidemiologic transition on national stunting rates. A level one unit is country-year, while a level two unit is a country. Each country thus has two time points for measures of demographic transition, epidemiologic transition, national stunting rates, and proximate macro-economic force, with the exception of the three economic forces. Because the data availability and the long-term effects as postulated by the theories of preceding economic forces have been well documented, the measures of these preceding economic forces were one point in time as specified and used in previous cross-national studies.

Also included in the analysis is the time-specific effect using 2008 as a control for the synchronization effect and 2013 for the time-lag effect; a negative sign signifies a decline in national stunting compared to the former period. The region-specific effect compares the global regions using region dummies, with Africa as an omitted category.[4]

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4 Some historical factors such as colonial heritage can explain why the effects of regional dummy variable (Asian countries) are statistically significant in affecting national stunting rates. However, because the region-specific effect was treated as a control variable, further theory development could enrich the framework through the inclusion of Asian countries for raising the variance explained.

VI. Findings

An examination of the determinants of national stunting rates must consider the influences of three economic forces, the proximate macro-economic force, as well as time- and region-specific effects as control variables by holding constant these control variables to constitute a complete model test. A preliminary analysis of the impact of demographic transition as measured by the indices of a global fertility and cultural transition reveals that the various indices exhibit the expected robust effects ($p<0.001$) on national stunting rates for both sexes (table not presented). An alternative analysis using this complete model plus the effect of an index of favorable conditions of population health further confirms the impact of demographic transition, but not the effect of favorable conditions of population health. In accord with the theoretical expectation, demographic transition affects favorable conditions for population health, and the interaction of demographic transition and favorable conditions for population health impact the subsequent epidemiologic transition. It is apparent that more immediate programs and policies for stunting reduction are probable influencing factors rather than the distal favorable conditions for population health.

The broader framework for contextualizing stunted child growth within the influences of the demographic and epidemiologic transition can be examined in Tables 2 and 3. Consistent with the preliminary analysis, the inclusion of both the measures of the demographic and epidemiologic transition in a full model test shows that both measures exert the anticipated robust effects on national stunting

Table 2: Random effects model estimates of national stunting rates for men using various indices of a global fertility and cultural transition and epidemiologic transition for less-developed countries

	(1)	(2)	(3)	(4)	(5)	(6)
d2008	−1.9142 (−1.07)	−1.8045 (−1.02)	−1.8601 (−1.05)	−1.8235 (−1.06)	−1.7077 (−0.97)	−1.1053 (−0.69)
Proximate economic force	0.0390 (0.01)	−1.0712 (−0.35)	−1.2743 (−0.44)	−0.0345 (−0.01)	0.2966 (0.10)	−3.3290 (−1.53)
gFACT4	−2.0818** (−2.85)					
gFACT3		−2.2331* (−2.39)				

Table 2: Random effects model estimates of national stunting rates for men using various indices of a global fertility and cultural transition and epidemiologic transition for less-developed countries (continued)

	(1)	(2)	(3)	(4)	(5)	(6)
gFACT2-NETTFR			−3.2228** (−2.60)			
gFACT2-TELIMR				−4.0456** (−2.87)		
gFACT2-NETIMR					−3.9124*** (3.42)	
Median age						−1.3996** (−3.03)
Ln(p2/p1)	−6.5099** (−2.90)	−7.0946*** (−3.22)	−7.0578*** (−3.23)	−6.4324** (−2.95)	−7.1910*** (−3.40)	−7.3443*** (−3.64)
Initial economic development	−0.0020 (−0.81)	−0.0028	−0.0017 (−0.69)	−0.0019 (−0.81)	−0.0022 (−0.94)	0.0013 (0.56)
Investment dependence	−0.0009 (−1.76)	−0.0017 (−0.68)	−0.0008 (−1.62)	−0.0010* (−2.02)	−0.0010 (−1.94)	−0.0010* (−2.07)
Trade dependence	1.3624 (0.50)	−0.0008 (−1.65)	1.0692 (0.39)	2.0148 (0.74)	1.6951 (0.64)	1.6209 (0.62)
Techno-economic heritage	−0.5423 (−0.56)	−0.6118 (−0.62)	−0.4983 (−0.51)	−0.9539 (−1.02)	−0.5865 (−0.63)	−1.0317 (−1.15)
Middle East	0.7727 (0.11)	0.5137 (0.07)	−0.5599 (−0.08)	4.5615 (0.70)	1.1513 (0.17)	−2.0363 (−0.30)
South America	7.3182* (1.98)	6.7484 (1.82)	6.6212 (1.81)	7.9560* (2.14)	7.9554* (2.21)	5.5300 (1.57)
Asia	9.4318* (2.22)	9.3509* (2.20)	9.6347* (2.31)	9.7179* (2.31)	9.2229* (2.24)	12.5064*** (3.10)
Constant	35.9471	44.6015	47.6413	36.9811	34.0822	92.9230
R^2	0.7541	0.7509	0.7546	0.7501	0.7575	0.7618
N/Observations	52/81	53/83	53/83	52/84	52/82	54/87

Notes: *t* statistics in parentheses. *$p<0.05$, **$p<0.01$, ***$p<0.001$; Africa is the reference category. See Appendix I for descriptive statistics and Appendix II for countries included in the analysis.

Table 3: Random effects model estimates of national stunting rates for women using various indices of a global fertility and cultural transition and epidemiologic transition

	(1)	(2)	(3)	(4)	(5)	(6)
gFACT4	−2.0045** (−2.64)					
gFACT3		−2.0676* (−2.13)				
gFACT2-NETTFR			−3.0166* (−2.34)			
gFACT2-TELIMR				−4.0589** (−2.77)		
gFACT2-NETIMR					−3.8064*** (3.21)	
Median age						−1.3996** (−3.03)
Ln(p2/p1)	−6.3090** (−2.69)	−7.0118** (−3.05)	−6.9493** (−3.04)	−6.0818** (−2.66)	−7.1910*** (−3.40)	−7.0287** (−3.17)

Notes: *t* statistics in parentheses. *$p<0.05$, **$p<0.01$, ***$p<0.001$
To conserve space, the results for the proximate economic force, three economic forces, time-specific effects, region-specific effects, and gFACT2-TELTFR are not presented in the table.

rates for both men (Table 2) and women (Table 3).[5] In addition to the expected significant effects of the different indices of demographic transition, using median age as an alternative of demographic transition also yields the expected significant impact (Tables 2 and 3). This test of the synchronization effect is robust and strongly supports the proposed thesis.

A further test of the five year time-lag effect yields a very similar result (table not presented). However, only two measures of demographic transition (gFACT2-TELIMR and gFACT2-NETIMR) reach a significant level, as does the synchronization effect, and all the effects of epidemiologic transition remain very significant. It should be noted that in the re-conceptualization of demographic transition as a global fertility and cultural transition, the construction of indices uses infant

5 Taking the first equation of Table 2 as an example, sigma_U is 5.772, sigma_e is 5.112, and the intraclass correlation (rho) is 0.5601, that is, 56.01% of the variance is due to differences across panels; the effect does exist across the two specified periods.

mortality rate (IMR), representing the early phase of demographic transition. In other words, the early reduction in infant mortality rate accompanying the following epidemiologic transition persists in affecting child stunting, while the later reduction in total fertility fails to demonstrate its influence. Depending on the indices of demographic transition measured, it seems that the test of the time-lag effect revealed both a partial direct and an indirect effect of demographic transition on child stunting, given that demographic transition was measured at 1995 and 2000, and epidemiologic transition was measured at 2000 and 2008 respectively. The robust synchronization effect supports the contextualization thesis to contextualize child stunting with a broader framework of demographic transition and epidemiologic transition. For the time-lag effect, it seems that a direct and an indirect effect of demographic transition in affecting national stunting provide only partial support for the proposed thesis.[6]

The robustness of the proposed model can be assessed by controlling the competing effects of women's education and autonomy, food supply, income inequality, macroeconomic shocks from globalization, and FDI in primary, secondary, and tertiary sectors. Previous studies have highlighted the health impacts of macroeconomic crises (Pongou et al., 2006; Smith and Haddad, 2002) and macroeconomic shocks (Stevens et al., 2012), poverty (based on GNI) as a determinant of stunting (Marriott et al., 2012), the importance of maternal education and autonomy on child health and stunting (Semba et al., 2008; Shroff et al., 2009), the role of economic inequality on stunted growth (Reinbold, 2011), and the effect of FDI on food supply and malnutrition (Mihalache-O'keef and Li, 2011). Table 4 shows the results of these control measures and unequivocally confirms the strong

6 This test of the time-lag effect can also collect more available annual data on national stunting rates. Annual data for measures of male stunting for 2000 to 2007 were set for the first period, and those for 2008 to 2013 for the second period, consistent with the two time point specification. A preliminary analysis shows $R^2=0.7554$ (with 52 nations and 155 observations, rho$=0.5827$); epidemiologic transition remains the most significant variable in affecting national stunting (coefficient$=-6.814$, $p<0.001$). Demographic transition as measured by gFACT2-TELIMR or gFACT2-NETIMR (using infant mortality rate for the index construction) is statistically significant and supports the direct effect of demographic transition on national stunting, while the other measures (using total fertility rate for the index construction) do not reach a significant level, revealing an indirect effect of demographic transition. This indirect effect, however, confirms the causal effect of demographic transition on epidemiologic transition (Malina et al., 2008; Chen, 2014), and the intermediate role of epidemiologic transition in affecting national stunting. Overall, this re-test with more available annual data provides further support for the synchronization effect as proposed by the contextualization thesis, whereas the time-lag effect provides only partial support of the proposed thesis.

Table 4: Robustness tests for national stunting rates (both sexes)

	(1)	(2)	(3)	(4)	(5)
Ln(p2/p1)	−9.0179*** (−3.50)	−5.0255* (−2.52)	−7.2134*** (−4.45)	−4.4768** (−2.91)	−7.5269*** (−3.49)
gFACT4	−2.6839** (−2.65)	−2.8252*** (−3.29)	−1.9949*** (−3.38)	−2.3318** (−3.13)	−2.2207** (−2.66)
Female to male enrollment	0.0179 (0.20)				
Secondary enrollment	0.0138 (0.12)				
Contraceptive prevalence	0.0890 (0.63)				
Caloric intake per capita		0.0235* (2.53)			
Protein intake per capita		−5.5383* (−2.55)			
Income inequality			−0.2462 (−1.84)		
Globalization				0.1491 (0.84)	
Primary FDI					−0.1355 (−0.22)
Secondary FDI					−0.9426 (−1.12)
Tertiary FDI					0.2948 (0.64)
Constant	22.2509	34.6757	52.4357	30.8547	48.0315
R^2	0.8142	0.8507	0.7763	0.7468	0.8477
N/Observations	43/65	30/57	54/100	48/91	28/46

Notes: *t* statistics in parentheses. *$p<0.05$, **$p<0.01$, ***$p<0.001$

All robustness tests for the three economic forces, time-specific effects, and region-specific effects are not presented in the table.

Data of female to male ratio of secondary school enrollment, secondary enrollment, and contraceptive prevalence around 1998 and 2003 were obtained from the *World Development Indicators* (The World Bank, 1995–2000) and the *Demographic Yearbook* (United Nations, 1995–2000). Income inequality in 1995 and 2000 were from the “Standardizing the World Income Inequality Database” (Solt, 2009). Caloric intake per capita, protein intake per capita, and FDI for primary, secondary, and tertiary sectors were obtained from Mihalache-O’keef and Li (2011).

influence of both measures of the demographic and epidemiologic transition on national stunting rates; moreover, all of the control variables yield a relatively negligible impact.

The robust effects of the demographic and epidemiologic transition can be emphasized by cross-tabulating the measures of the two transitions to examine the changes in national stunting rates for men, women, and both sexes combined across two periods. The data in Table 5 further support the efficacy of the proposed framework. For those countries located at the lower levels of transition, changes in national stunting rates for two periods are relatively limited, as indicated in the shift from 48.22 to 41.38 for men, 43.2 to 35.98 for women, and 45.71 to 38.68 for both sexes combined. A rise to the medium levels of transition indicates some improvements for men (from 35.5 to 31.46), women (from 33.52 to 28.61), and both sexes combined (34.87 to 29.19). The most notable reduction can be observed at the high levels of transition—from 14.03 to 9.83 for men, 11.93 to 9.29 for women, and 13.06 to 9.69 for both sexes combined. Overall, the proposed framework facilitates an examination of the changes in national stunting rates following the progression of the demographic and epidemiologic transition. Between the two transitions, demographic transition appears to exert the most salient impact on changes in national stunting rates, as indicated by the lowest levels of stunting at the high level of demographic transition.

Table 5: Changes in mean national stunting rates for men, women, and both sexes combined across two periods around 2000 and 2008 following various levels of demographic transition (gFACT4) and epidemiologic transition [Ln(p2/p1)]

	Low Ln(p2/p1)			Medium Ln(p2/p1)			High Ln(p2/p1)		
		2000	2008		2000	2008			
Low gFACT4	Men	48.22	41.38	Men	48.22	44.15			
	Women	43.20	35.98	Women	45.08	41.48			
	Both	45.71	38.68	Both	45.54	42.86			
		2000	2008		2000	2008		2000	2008
Medium gFACT4	Men	35.10	30.77	Men	35.50	31.46	Men	27.07	19.56
	Women	29.85	26.18	Women	33.52	28.61	Women	23.43	16.95
	Both	32.27	27.87	Both	34.87	29.19	Both	24.69	18.28
					2000	2008		2000	2008
High gFACT4				Men	12.73	12.85	Men	14.03	9.83
				Women	8.76	11.62	Women	11.93	9.29
				Both	12.51	12.22	Both	13.06	9.69

VII. Conclusion

The proposed framework of demographic and epidemiologic transition can contextualize changes in stunted child growth and development in a more meaningful and constructive manner not addressed in previous studies. The full model incorporating the influence of three economic forces as well as time- and region-specific effects confirms the efficacy of the proposed framework for examining changes in national stunting rates. The synchronization effects of both demographic transition and epidemiologic transition support the proposed contextualization thesis, while the time-lag effect provides only partial support of the proposed thesis. A critical implication of these findings is that such endeavors must first trace the progression of demographic transition and the accompanying favorable conditions of population health to mobilize the necessary epidemiologic transition from communicable to non-communicable diseases. Consequently, the proposed framework can contribute to the positive contextual conditions ideal for framing nutrition advocacy and promoting healthy growth through the guiding of adequate programs, policies, and strategies. Hopefully, the findings of this study can contribute substantively to the eventual nutrition transition and stunting reduction for less-developed countries.

Some limitations of the study can be stated as follow: first, all other control variables not included in the analyses such as government or public health intervention can be further brought into the equations to testify the efficacy of the model. Given the robust findings and the strong theoretical bases, it can be expected that the proposed model can withstand any other additional controls. Second, this study has its limitations in not fully accounting for the details of cross-level analyses and a structure-agency linkage on how demographic transition can be linked to the ongoing efforts combining direct nutrition interventions with strategies, policies, and programs to foster multi-sectoral plans and the development of governance concerning an accountability framework and surveillance systems. All these leave some directions for further studies in the future.

Appendix I: Basic descriptive statistics

	N	Min	Max	Mean	S.D.	Skewness	S.E.
Stunted men 2000	72	4.50	65.50	36.3014	15.84630	−.200	.283
Stunted women 2000	72	3.30	60.80	32.4750	15.14969	−.132	.283
Stunted both sexes 2000	91	3.10	63.10	31.3396	15.96564	.078	.253
Stunted men 2008	81	2.20	61.70	30.4062	14.49099	−.109	.267
Stunted women 2008	81	1.80	58.50	27.1370	13.31316	−.036	.267
Stunted both sexes 2008	85	2.00	59.30	28.1682	13.89049	−.010	.261
(Ln) GDPpc 1995	57	6.11	10.15	7.9321	.94340	.163	.316
(Ln) GDPpc 2000	64	5.50	10.66	8.0111	1.20589	.141	.299
gFACT4 2000	87	−8.73	5.78	−.0390	3.62720	−.482	.258
gFACT3 2000	89	−6.03	4.59	−.0069	2.73673	−.365	.255
gFACT2-NETTFR 2000	89	−4.23	3.18	.0036	1.87791	−.407	.255
gFACT2-TELTFR 2000	121	−3.96	2.61	.0094	1.93515	−.470	.220
gFACT4 1995	114	−7.62	5.01	−.0011	3.77467	−.433	.226
gFACT3 1995	117	−6.44	3.94	.0298	2.86574	−.379	.224
gFACT2-TELTFR 1995	121	−3.96	2.61	.0094	1.93515	−.470	.220
gFACT2-NETTFR 1995	117	−4.35	2.74	.0249	1.90515	−.357	.224
Ln(p2/p1) 2000	96	−1.17	2.99	.7728	1.16636	.053	.246
Ln(p2/p1) 2008	96	−.91	3.08	1.0504	.98017	.094	.246
Initial economic development 1980	113	250.00	8089.00	2334.1239	2108.25035	1.124	.227
Transnational corporate penetration 1967	101	129.00	10500.00	4955.5149	3384.87759	.375	.240
Trade as % of GNP 1965 (Ln)	105	1.99	5.47	3.6956	.61989	.068	.236
Agricultural density (Ln)	106	2.64	12.85	6.9756	1.66666	.338	.235

Appendix II: Countries included in the analysis

Depending on data availability and the sample selection following the stringent method of list-wise deletion, the countries included in the analysis are roughly representative of different regions and both semi-periphery and periphery of all developing countries. Taking equation 2 in Table 2 as an example, there are 9 semi-periphery countries, 44 peripheral ones, 26 in Africa, 8 in Asia, 17 in Latin America, and 2 in the Middle East:

Algeria, Angola, Benin, Cameroon, Central African Rep, Egypt, Ghana, Kenya, Madagascar, Mauritania, Malawi, Mali, Morocco, Mozambique, Nigeria, Niger, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Togo, Tunisia, Uganda, Zambia, Zimbabwe, Afghanistan, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand, Turkey, Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Rep, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Peru, Iraq, Jordan.

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人口轉型與疾病轉型脈絡下的兒童生長遲緩發展

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摘　要

本研究提出以人口轉型與疾病轉型廣泛的架構解釋開發中國家兒童生長遲緩率的發展。完整的隨機效果模型涵蓋三個先前經濟力、晚近總體經濟力、時間特定效果以及區域特定效果所進行的跨國資料檢驗，強烈支持人口轉型與疾病轉型對開發中國家兒童生長遲緩發展影響的同時效果與部分時間遞延效果。本研究有其廣泛之政策涵義。

關鍵字：人口轉型、疾病轉型、兒童生長遲緩發展

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