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A city and national metric measuring isolation from the global market for food security assessment

Molly E. Brown [a,*], Kirk C. Silver [b], Krishnan Rajagopalan [c]

[a] Biospheric Sciences Laboratory, Code 618, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
[b] College of the Environment and Life Sciences, 106 Coastal Institute – MESM, University of Rhode Island, Kingston, RI 02881, USA
[c] Mathematics Department, 121 Blake Road, U.S. Naval Academy, Annapolis, MD 21402, USA

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A B S T R A C T

The World Bank has invested in infrastructure in developing countries for decades. This investment aims to reduce the isolation of markets, reducing both seasonality and variability in food availability and food prices. Here we combine city market price data, global distance to port, and country infrastructure data to create a new Isolation Index for countries and cities around the world. Our index quantifies the isolation of a city from the global market. We demonstrate that an index built at the country level can be applied at a sub-national level to quantify city isolation. In doing so, we offer policy makers with an alternative metric to assess food insecurity. We compare our isolation index with other indices and economic data found in the literature. We show that our Index measures economic isolation regardless of economic stability using correlation and analysis.

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Introduction

Global commodity prices have seen enormous variability and change in the past five years (Trostle, Marti, Rosen, & Westcott, 2011, p. 29). These changes have driven significant anxiety among policy makers and low-income consumers around the world, fearing the impact of changing food prices on the ability of the poorest people to access adequate food. Higher global commodity prices will affect food security when countries or regions import food from the global marketplace and the higher cost of this food subsequently affects local food prices (Darnton-Hill & Cogill, 2009; Ravallion, 1991, p. 34; Thompson, 1983). The degree to which changes in the international commodity market affect local prices depends on the market's isolation from the world market (Brown et al., 2012).

Many of the least developed countries are isolated from the international market by some degree (Brown et al., 2012). In poor agricultural countries, economic isolation restricts development while at the same time protects farmers and consumers from international price fluctuations. Reduced access to imported food increases the cost of food during periods of drought when local production is reduced. Isolation also serves as a substantial barrier for farmers to sell their goods outside of their local region (Aker, Klein, O'Connell, & Yang, 2010). Built infrastructure has long been recognized as an important element to development and strengthening of local markets (Briceño-Garmendia, Estache, & Shafik, 2004).

The cost of transporting goods from a port to a market is associated with different degrees of cost-efficiency per distance traveled. Adequate infrastructure (roads, rail, law enforcement, etc.) is critical for ensuring reasonable transaction costs for low value, high bulk goods such as grain. Variations in the quality of transport infrastructure by country and the impact of improvements in infrastructure on food markets have not been systematically evaluated (Briceño-Garmendia et al., 2004).

In less developed regions of the world, such as Africa, problems with transportation infrastructure are compounded with issues of broader economic development. Despite rapid growth in the region's economy in the past decade, Africa's share in world trade has been falling since the 1980s (UNCTAD, 2003, p. 24). The proportion of the economy in manufacturing has fallen from 15% in 1990 to 10% in 2008. This trend is particularly strong in West Africa, where the proportion of economy in the manufacturing sector fell from 13 to 5 percent during the same period (UNCTAD, 2012, p. 161). Trade in the manufacturing sector provided revenue that was used to support and maintain transportation infrastructure. Reductions in manufacturing seen in Africa since 1990 may have a significant impact on the ability of the individual countries to support their transportation infrastructure, and reduce their

* Corresponding author.
E-mail address: molly.brown@nasa.gov (M.E. Brown).

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ability to reach development targets laid out in the Millennium Development Goals (MDGs) (Majid, 2004).

Population expansion during the past few decades has resulted in significant increases in the demand for food. This demand has been met largely from globally marketed cereal and food products because of their relatively low cost and ease of use. The inability of most countries within Africa to grow enough food to feed its people is often due to population growth, low and stagnating agricultural productivity, policy distortions, weak institutions, and poor infrastructure. In addition, food import dependency is closely related to a country's income (Rakotoarisoa, Iafrate, & Paschali, 2011, p. 89). Trade is an excellent buffer for domestic fluctuations in food supply because there is adequate food for all at the global scale. Food security crises are caused by the inability to move adequate food across borders from surplus to deficit areas. Movement of goods may be hindered by political, economic, or physical barriers that isolate the deficit region. Isolation further inhibits agricultural production through restriction of infiltration of new technology, improved plant varieties, and other agricultural inputs. Isolation due to inadequate infrastructure is a critical barrier to achieving food security in many regions.

The overarching objective of this paper is to create a metric that enables the comparison of the differences in built transportation infrastructure across all economies. To reach this objective, we first derive a country-level isolation metric from universally available data that measures the economic vitality and connectedness of each country with the international market. Then we measure the distance between a country's primary port and its capital city, or other community of interest. We use this distance metric for each city and scale it using the country-level metric for each country through which the goods must travel. Although the specifics around pairing a given city with a particular port and measuring distance can be modified, our method is powerful in the logical process used to arrive at city isolation. Finally, we compare the resulting metric to existing measures of economic activity and food security to explore its usefulness and originality.

Isolation and its definition

The type of isolation we aim to quantify is a measure of accessibility. The question we wish to answer is depending on a city's location, how connected is it with the market for globally traded commodities? This assumes that economic measures and the stability afforded by local government are not factors. As such, the index is primarily a measure of strength of infrastructure. Economic contributors are not included so as to empower the index in its application to understanding trade and market isolation. We did not want differences in economic activity to be captured in the explanatory variables. In addition, measures of societal stability were too subjective to incorporate quantitatively in the Isolation Index we present here. The lack of consistency would weaken the index's ability to be applied globally. We recognize the importance of economic factors and societal stability in assessing isolation, but they are excluded to reduce subjectivity and allow the use of the Isolation Index with these economic indices in later analysis. There are many other metrics of isolation that do include these parameters (see Table 2 for examples). Our contribution is in the development of a comparable, international isolation metric that can be applied to a city or nation that excludes these considerations.

Central to the development of an Isolation Index is acknowledging the importance of maritime trade. It is the most commonly used means of international trade as approximately 80% of the world's trade is conducted by sea (Vego, 2008). Considering this, it is crucial to pair inland cities with specific major, industrialized ports that are likely to be employed to import bulk commodities.

Table 1
Inputs to the isolation metric.

Explanatory variable $j \in P$	Description	Input (x_{ij})	Source
Geographic area (ga_i)	Sum of all land and water areas in square kilometers	None	CIA
Airports (ar_i)	Total number of airports or airfields recognizable from air	ar_i/ga_i	CIA
Airports paved (ap_i)	Total number of airports with paved runways	ap_i/ga_i	CIA
Airports infrastructure (ai_i)	Percent airports paved of total	ap_i/ar_i	CIA
Roads (ro_i)	Total length of road network in kilometers	ro_i/ga_i	Nationmaster
Roads paved (rp_i)	Total length of paved roads of network in kilometers	rp_i/ga_i	Nationmaster
Roads infrastructure (ri_i)	Percent roads paved of total	rp_i/ro_i	Nationmaster
Railways (rl_i)	Total length of rail network in kilometers	rl_i/ga_i	International Union of Railways
Ports (pt_i)	Number of major coastal and inland ports	pt_i/ga_i	CIA
Coastline (co_i)	Total length of land boundary touching sea in kilometers	co_i/ga_i	CIA
Inland water (iw_i)	Total area of all inland water bodies in square kilometers	iw_i/ga_i	CIA

Thus, we consider a city's isolation to be a measure of its accessibility from its associated port. The issue then becomes how to quantify this accessibility. Relying upon distance alone is not sufficient. Travel time and transport efficiency rely too heavily upon regional infrastructure strength to base accessibility upon distance alone (World Bank, 2012).

Index development

There are two widely accepted paths that may be used to develop an index: a network-flow optimization model (Magle, Theobald, & Crooks, 2009) and a statistical approach (Briguglio, 1995). Magle et al. (2009) implement a network optimization model in an effort to quantify the level of isolation amongst prairie dog populations in the Denver, CO area. Nodes of the model indicate location of prairie dog populations with the connecting arcs weighted by the presumed relative difficulty of traveling along such a path. Because the authors were able to directly measure the difficulty of travel using clearly defined methodology and comparable datasets, the metric is effective at measuring the isolation of one community from another (Magle, Theobald, & Crooks, 2009). Although this approach would meet the objective of creating an index that quantifies transport convenience across diverse areas of the world, there is simply not enough specific, comparable infrastructure quality information and travel time data to construct accurate models for our purposes.

We use a statistical approach to measure isolation using freely available economic factors as explanatory variables, adapting Briguglio's (1995) method to index the vulnerability of small islands. His technique of standardizing the variables is of particular interest to us because the author addresses multiple factors with different units and produces a single, meaningful number that can be comparable across economies and locations. The author's primary concern is that the method be simple and thus easily replicated. We adopt a similar approach to Briguglio and also employ methods from the Konjunkturforschungsstelle, or KOF Index of Globalization, in weighting the explanatory variables of the index (Dreher, 2006). Dreher (2006) weighs variables in such a way