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Hydrological hazard assessment: THE 2014–15 Malaysia floods

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ABSTRACT

This paper intends to establish conceptual foundations on the identification of standards and metrics for assessing the impact of hydrological hazards. The economic evaluation of flood damage cost model (EFDC-Model) attempts to estimate the impact of water occurrence, movement, and distribution on GNP growth. The model is based on seven basic indicators: (i) the national precipitation growth rate (ΔP_i); (ii) the main factors which generate large precipitation (ΔL_i); (iii) the sinking magnitudes levels rate (S_T); (iv) the national floods recurrence rate (F_T); (v) the floods devastation rate (D_k); (vi) the economic desgrowth from floods devastation rate ($-\delta_f$); and (vii) the floods damage surface. The model investigates the recent floods in the Malaysian states of Kelantan and Terengganu for the period 2014–2015.

1. Introduction

Malaysia experienced one of the most devastating floods in decades. On 17 December 2014, there were 3390 people in Kelantan and 4209 in Terengganu evacuated [1]. The persistence of precipitations rose the water level on most of the rivers in Kelantan, Pahang, Perak and Terengganu beyond safety levees, which caused the evacuation of approximately 60,000 people on the following day. The aftermath of flooding damages estimated by the Malaysian government mounted to 1 billion ringgits ($284 million USD), from which, 100 million ringgits disposed to repair roads in Kelantan and 132 million ringgits to repair roads in Terengganu [2]. The last time the region experienced flood hazards was in 2000 where 15 people killed and more than 10,000 people fled their homes [3].

The paradigm of Malaysia hydrological hazards illustrates the level of physical, social, economic, and environmental vulnerability of the affected areas [4–7]. Emerging literature argues that relief and recovery expenditures can have significant repercussions to country's national debt with negative short-run and long-run implications on the overall economic performance of a country[1] [12–16]. For developed countries, empirical findings shown no aggregate macroeconomic short or long run effects [17,18] and the literature focuses generally on direct and indirect impacts and regional economies [19]. On the contrary, the macroeconomic impact of natural disasters is restricted to developing countries [20–26].

The type and degree of perceived risk varies greatly according to vulnerability, magnitude, intensity, spatial attenuation, duration, frequency of occurrence, and precipitation trends [27]. Comparatively low-intensity, local scale incidents usually have an insignificant impact in country's economic performance. But sometimes, even a limited-in-magnitude natural event can affect a country's macroeconomic performance if a country's main economic activity is hit.[2] However, some main factors which contribute to macroeconomic vulnerability can be determined: the type of natural hazard, the economic structure, the geographical area and scale of impact, the stage of development and the prevailing socioeconomic conditions [29–33].

This paper aims to study the impact of floods on the macroeconomic performance. We set forth a model – the economic evaluation of flood damage cost model (EFDC) model – and evaluate the impact of floods on GNP growth. The model is based on seven basic indicators: (i) the

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[1] Econometric analyses have been reached contradictory conclusions. [8] Dell, M., B.F. Jones, and B.A. Olken, *Wha Do We Learn from the Weather? The New Climate-Economy Literature.* Journal of Economic Literature, 2014. 52(3): p. 740–798. [9] Kousky, C., *Informing climate adaptation: A review of the economic costs of natural disasters.* Energy Economics, 2014. 46(2014): p. 576–592. Albala-Bertrand [10] Albala-Bertrand, J.M., *Political economy of large natural disaster*. 1993, Oxford, UK: Clarendon Press. and Skidmore and Toya. [11] Skidmore, M. and H. Toya, *Do Natural Disasters Promote Long-run Growth?* Economic Inquiry, 2002. 40(4): p. 664–687. suggested that natural disasters have a positive influence on long-term economic growth, probably thanks to the stimulus effect of reconstruction and possibly the replacement of damaged capital with more recent technologies.

[2] For example, in 1987 an earthquake destroyed the most important oil pipe in Ecuador (loss ratio to GDP of 1.8%), cutting down the oil exports for several months. [28] Albala-Bertand, J.M., *Disasters and the Networked Economy*. Routledge Studies in Development Economics. 2013, Oxon, UK: Routledge.

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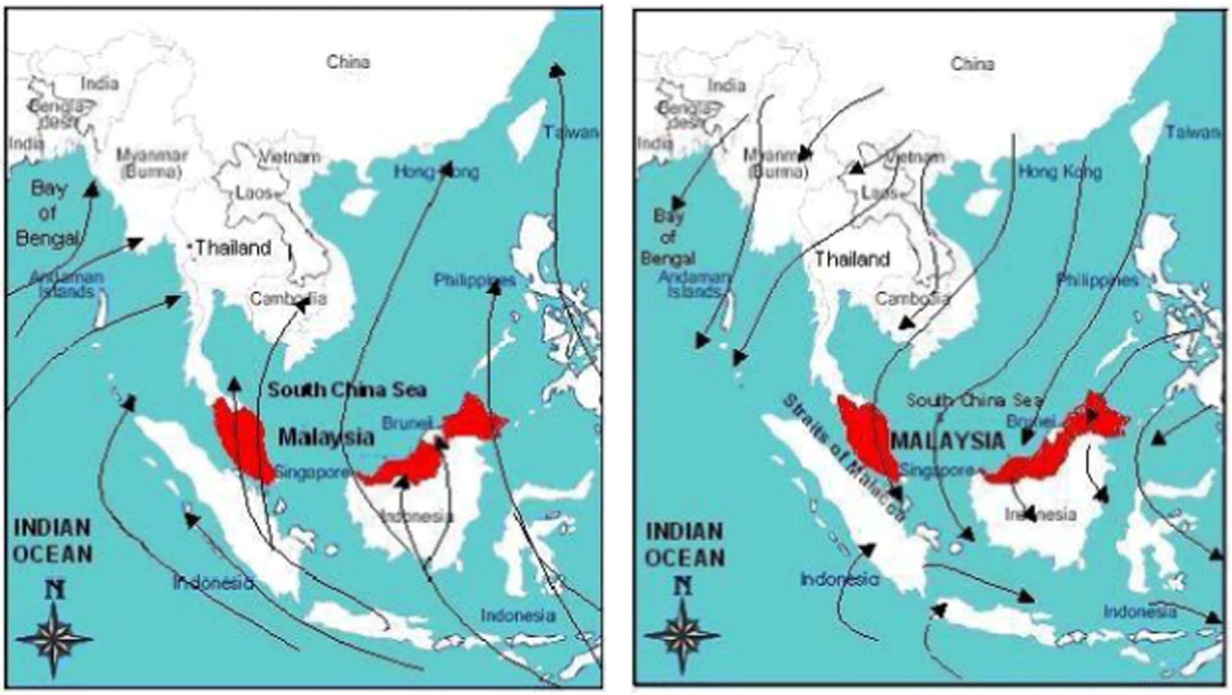

Fig. 1. Southwest and Northeast Monsoons.
Source: [6]

national precipitation levels rate, ΔP_i; (ii) the main factors which generate large precipitation, ΔL_i; (iii) the sinking magnitudes levels rate, S_T; (iv) the national floods levels rate, F_T; (v) the floods devastation level rate, D_k; (vi) the economic desgrowth from floods devastation rate, $-\delta_f$; and (vii) the floods damage surface. The model investigates the recent floods in the Malaysian states of Kelantan and Terengganu for the period 2014–2015.

2. Economic modeling in the evaluation of floods

Numerous frameworks, conceptual models, and vulnerability assessment techniques have been developed to advance both the theoretical underpinnings and practical applications of vulnerability and hazard calculations to natural disasters. The early designs of hydrological hazard protection systems were based on cost-benefit analyses [34–39]. Alternative stream of literature employs vulnerability assessment approaches to create a comprehensive baseline for flood analysis based on population level data [40–46]. The new generation of researchers have the tendency of use Computable General Equilibrium (CGE) models [47–52].

While several research efforts have assessed various dimensions of community resilience, challenges remain in the development of consistent factors or standard metrics that can be used to evaluate the flooding disaster resilience of communities. In this respect, the EFDC model brings an innovative mathematical and graphical approach, which provides crucial, timely information needed to forecast the unforeseen behavior of hydrological phenomena. The EFDC model set new course in mathematical modeling that captures a comparative evaluation between *ex ante* and *ex post* forecasts, develops a set of common indicators, and test it in real-world application.

3. Methodology

3.1. Description of the study area

Malaysia lies geographically near the equator characterized by where temperatures remain relatively constant throughout the year. Tectonically outside of the circum-Pacific belt, Peninsular Malaysia to the west and East Malaysia to the east are free from volcanic eruptions and earthquakes. The climates of the Peninsula and the East differ, as the climate on the peninsula is directly affected by monsoons from the mainland, as opposed to the more maritime weather of the East (see Fig. 1).

Malaysia is exposed to the El Niño effect, which reduces rainfall in the dry season. Climate change is likely to have a significant effect on Malaysia, increasing sea levels and rainfall, increasing flooding risks and leading to large droughts. The country has experienced severe flooding in the recent decades, including overbank flooding of rivers and streams and shoreline inundation along lakes and coasts. The most areas are mainly located at the river basins in Penang (Juru River Basin), Pahang (Pahang River Basin), Terengganu (Setiu River Basin) and Perak (Kinta River Basin) [4]. Flooding typically results from large-scale weather systems generating prolonged rainfall or on-shore winds. Other causes of flooding include locally intense thunderstorms, snowmelt, ice jams, and dam failures. Flash floods, which are characterized by rapid on-set and high velocity waters, carry large amounts of debris. Floods are capable of undermining buildings and bridges, eroding shorelines and riverbanks, tearing out trees, washing out access routes, and causing loss of life and injuries.

As shown in Fig. 2, Terengganu and lesser Kelantan receive torrential precipitations during the northeast (November–February) and southwest (April–September) monsoon periods. The floods that occur in Terengganu and Kelantan states were due to the combination of physical factors such as elevation and also its close proximity to the sea apart from heavy rainfall received during the monsoon period. Hence, a flood that affects the Terengganu and Kelantan areas and other location along the eastern coast is termed as a coastal flooding [6]. According to the department of Hydrology, Malaysia has experienced forty four evolving floods in respect magnitude and severity since 1886 [3,5].

The Malaysia Meteorological Department conducted a temperature analysis comparing climate data for 1961–1990 and 1998–2007 obtained from various weather stations. According to their findings, the average long-term mean temperature has increased by about 0.5–1.5 °C and 0.5–1.0 °C in Peninsular Malaysia and East Malaysia, respectively.