



## Economic impacts of natural disasters in megacities: The case of floods in São Paulo, Brazil



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### ABSTRACT

The city of São Paulo, home to 11 million people, suffers constantly the effects of flooding caused by extreme precipitation. Localized floods occur every summer in various parts of the city. Besides the losses and inconvenience felt by the residents, floods produce damages that cross the city boundaries, affecting income and output in the metropolitan area as well as in other parts of the state and the country. The objective of this study is to evaluate the economic impacts of floods in the city of São Paulo through the use of a Spatial Computable General Equilibrium (SCGE) model integrated to GIS information related to the location of points of floods and the firms within their influence. It is estimated that floods contributed to reduce city growth and residents' welfare, as well as hampering local competitiveness in both domestic and international markets. An intra-city total impact-damage ratio of 2.2 and an economy-wide total impact-damage ratio of 5.0 were found.

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### Introduction

The relationship between urbanization of large agglomerations and flooding has been receiving more attention recently in the context of forecasted changes in the frequency and intensity of extreme events due to climate change (Gu, Hu, Zhang, Wang, & Guo, 2011; Linnekamp, Koedam, & Baud, 2011; Nobre et al., 2011).

There is a significant correlation between human occupation and urban drainage systems.<sup>1</sup> Urban development promotes changes in land use that increase flood hazards, as changes to stream channels can limit drainage during heavy rainfall (Konrad & Booth, 2002). Megacities such as São Paulo have numerous social and environmental problems associated with patterns of development and transformation of space, which have been aggravated by increases in temperature and intensification of extreme weather events (Dias, Dias, Carvalho, Freitas, Dias, 2013; Nobre et al., 2011). Projections of climate changes indicate a step up in the frequency

and intensity of short lasting extreme events, and point to an increase in the number of days with heavy rainfall until the end of the century, aggravating further the issue of flooding.<sup>2</sup>

The consequences of floods in urban areas are relevant, ranging from impacts on human health (Huntingford, Hemming, Gash, Gedney, & Nuttall, 2007) to effects on housing prices (Harrison, Smersh, & Schwartz, 2001), urban transportation infrastructure (Suarez, Anderson, Mahal, & Lakshmanan, 2005), and other damaging effects such as time lost in work and education, damages to property and psychological stress (Linnekamp et al., 2011); moreover financial costs are also important, through potential effects in the insurance sector and public compensation schemes (Botzen & Van den Bergh, 2008).

Van der Veen and Logtmeijer (2005) discusses [economic] vulnerability to flooding as a function of dependence – the degree to which an activity relates to other economic activities in the rest of the country; redundancy – the ability of an activity (or system)

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<sup>1</sup> The worsening of drainage problems in São Paulo has always been linked to the occupation of the Tiete River plain (Nobre et al., 2011; Ostrowsky, 1991).

<sup>2</sup> Even though projections of changes in rainfall and rainfall extremes may still show uncertainties due to climate model difficulties in representing some physical processes related to rainfall formation at higher resolutions (Marengo, Jones, Alves, & Valverde, 2009), significant positive trends are found in the evolution of daily rainfall extremes in the city of São Paulo from 1933 to 2010 historical data (Dias et al., 2013).

to respond to a disruption by overcoming dependence by deferring, using substitutes or even relocating; and susceptibility – the probability and extent of flooding. Understanding this functional tripod would be essential to identify risk-related economic hot-spots associated with a broader concept of damage which should include not only traditional direct damages related to infrastructure, property and business disruption, but also indirect costs measured through input–output linkages.

We operationalize this concept using an alternative methodological approach. The focus of the paper is on one specific dimension of the economic impacts of flooding in an integrated interregional system. We use as our case study all the flooding events that occurred in the city of São Paulo in 2008. As we will analyze every single point of flood in that year, treatment of susceptibility becomes of lesser importance; from the economic standpoint, once the flood took place in a point of the city, we will just need to verify the existence of affected business firms within its territorial extent. The other two elements are also explicitly considered. Dependence is fully captured through spatial linkages associated with the income flows and value chains embedded in the metropolitan input–output system used to calibrate the spatial computable general equilibrium (SCGE) model, and on hypotheses on interregional factor mobility; redundancy is contemplated on the strength of substitution effects induced by price effects and supply constraints in the SCGE model.

In an economic perspective, three main driving forces come into play: at first, businesses in the influence area of the flood points may have to shut down temporarily, hampering potential GDP/GRP growth through interruptions in their value chains; secondly, damage in the economic infrastructure may generate either a reduction in the capital stocks available for production or, more common in flood events, temporary disruptions of infrastructure services (e.g. electricity disruption, closing of roadways), also negatively impacting the potential GRP/GDP; and thirdly, reconstruction efforts and additional maintenance measures operate in the opposite direction, activating investment-oriented activities (e.g. construction sector), starting more vigorously after the flood periods. This paper aims to evaluate the effects of the first of these three driving forces. We look at the economies of the city of São Paulo and of Brazil in 2008 and estimate what would be the hypothetical economy-wide impact had all flood events not occurred in that year. In doing that, we are able to derive the estimates of the economic costs of the floods related to the value chains disruptions associated with businesses' temporary close downs during the events. By not taking into account the effects of neither disruptions in infrastructure services nor financial flows associated with recovery of the natural disasters, we are able to isolate the economic effects of the flooding and its spatial propagation providing an approximation of the regional consequences from a value chain perspective. Thus, these estimates should be considered as lower bounds of the broader economic costs.

The remaining of the paper is structured as follows. In the next section, we provide more information on the study area, followed by a section in which the methodology is described and estimates of direct effects are shown. The following section presents the economy-wide impacts of the 2008 floods in the city of São Paulo, emphasizing their systemic nature. Final remarks conclude.

## The study area

The São Paulo Metropolitan Region (SPMR), the main economic and financial center of Brazil, consists of 39 municipalities in an intense process of conurbation. It is the fourth largest urban agglomeration of the world, and the largest urban agglomeration in the country, with about 10% of the national population (around 20

**Table 1**  
Basic indicators.

	Area (000 km <sup>2</sup> )	Population (000 000)	GDP (USD billion)	Per capita GDP (USD)	HDI 2000
City of São Paulo	1.5	11.3	194.6	17,221	0.841
SPMR	7.9	19.7	306.5	15,558	0.813
Brazil	8,514.9	190.8	1,619.2	8,486	0.665

million inhabitants), and responsible for 19% of Brazilian GDP. The city of São Paulo is the core of the metropolitan area and accounts for 5.9% of the country's population and 12% of its GDP (Table 1).

From a stylized perspective, one can notice the existence of an extended central business district (CBD) associated with the spatial configuration of economic activities in the metropolitan area. The CBD concentrates the jobs, while households are located in the surroundings of the center, with population density decay in the boundaries of the territory of the metropolis. As suggested by Figs. 1 and 2, the internal organization of the SPMR can be approached by a Muth–Mills–Alonso urban model, having as the CBD the extended center of the city of São Paulo. According to the 2010 population census, the city of São Paulo receives daily an inflow of almost 1 million commuters, representing 15.4% of workers in the city.<sup>3</sup>

Dense urbanization is a significant source of heat. The densest parts of the metropolitan area tend to be the warmest, and temperature decreases as urban density declines (Nobre et al., 2011). The “urban heat-islands” create more summer rain over and downwind of major cities (Shepherd, Pierce, & Negri, 2002), reinforcing the forecasted trends of increasing frequency and intensity of daily rainfall extremes in the city of São Paulo (Dias et al., 2013).

The rapid process of urban expansion around the CBD (Fig. 3) was not followed by the implementation of adequate infrastructure, causing important urban problems. Due to the lack of urban planning and the illegal occupation of the environmental protection areas (around watercourses and on slopes), the percentage of impervious areas in the Upper Tietê River Basin, the main watercourse in the city, has increased significantly. As a result, flood frequency in the basin has also increased (Barros, Brandão, Silva, Ono, 2005).

Among the main issues currently faced by the city are those related to climate change. The intense rainfall in the summer causes floods in several points of the town. Besides the loss and inconvenience suffered by people directly affected, these floods produce wider effects that surpass the limits of the city, reflecting on economic sectors of the state and the country. The impacts of floods affect households, industrial and commercial activities, public and private services, and the urban transportation system. Given the increasing concentration of people and economic activities in the area in the past decades, impacts and economic losses due to natural catastrophes have increased substantially.

Since the early 1970s, the SPMR has undergone major structural changes, transformed from dominance by traditional manufacturing to more sophisticated services.<sup>4</sup> The hollowing-out process of the metropolitan area associated with the geographical de-concentration of the manufacturing sector has imposed a new structure of interregional dependence in which SPMR plays a specific role. On one hand, a typical establishment is now less dependent both on sources of inputs and on markets within the metropolitan area. On the other hand, fragmentation is now a

<sup>3</sup> Around 170,000 of São Paulo residents commute daily to other cities, especially in the SPMR.

<sup>4</sup> The share of SPMR in the national manufacturing output dropped from over 40% in the 1970s to less than 20% in the recent years.

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