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Measuring and understanding the microeconomic resilience of businesses to lifeline service interruptions due to natural disasters

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ABSTRACT

Facing rising natural hazards, urban environments are particularly prone to suffer economic impacts from business interruptions due to disaster-induced lifeline service disruptions. Enhancing the ability of local economies to maintain function and hasten recovery in the aftermath of natural disasters triggers the need to both measure economic resilience and better understand its drivers. Based on a conceptual framework that highlights the peculiarities of resilience with respect to vulnerability and adaptation, this paper develops a scientifically sound operational indicator of the economic resilience of individual businesses to lifeline service interruptions caused by natural disasters. The indicator is constructed so as to compare patterns of economic resilience across firms or events and identify hotspots of poor resilience that public policies should target as a priority. In order to demonstrate its scientific and operational relevance, it is applied to individual businesses located in the Urban Community of Central Martinique (French West Indies). A business survey is used to collect empirical data for two hypothetical equal hazard scenarios leading to the disruption of the drinking water and electricity networks. An econometric analysis then investigates the dependence of economic resilience to a set of individual characteristics such as business demographics and operating characteristics. Results show that businesses are relatively more resilient to drinking water interruptions than to electricity cuts and that turnover and flexibility in both working hours and production processes are significant drivers of economic resilience. We discuss the limitations of this indicator and pinpoint the challenge for future research of isolating pre-existing sensitivity to shocks from overall economic impacts.

1. Introduction

In upcoming decades, impacts of natural disasters are likely to increase because of both changes in the occurrence and severity of extreme events and changes in the exposure and vulnerability of societies to natural hazards [35]. Meanwhile, the uncertainty of future threats and the complexity of integrated social, technical and economic systems, increase the challenge of performing disaster risk analysis, especially in dense urban environments. Because their results highly depend on uncertain and often unprecedented natural phenomenon, classical risk assessments are likely not to be sufficient to provide decision-makers with robust risk reduction strategies. A more pragmatic approach to disaster risk reduction consists in building resilience in socio-ecological systems in order to strengthen their ability to recover and adapt from adverse events of any kind [39]. Resilience assessments allow scaling-up the analysis framework so as to both enhance recovery and reduce risk while avoiding thoroughly accounting for the peculiarities of the initial hazard characteristics. As such,

they improve upon risk assessments to support decision-making under uncertainty.

Because they are the ultimate decision-makers of economic systems, businesses are a cornerstone in building resilience of local economies. Their resilience, that is their ability to cope with new physical and market conditions and maintain operations under stress, is crucial in the aftermath of extreme events. They ensure the provision of goods and services that are essential to sustain livelihoods and secure incomes for households, hastening thereby the recovery of entire communities. Measuring and understanding their resilience to disaster risks is an important contribution to design efficient resilience enhancement strategies [61,70]. However, any attempt to measure the economic resilience of businesses requires understanding their recovery process, which in turn depends upon the economic impacts they are likely to suffer.

Economic impacts of natural disasters fall into two broad categories: direct impacts, which arise directly from physical impacts, such as the cost of replacing a damaged building, and indirect impacts which are

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second-order downstream effects that result from the diffusion of physical impacts across the wider economic system, such as production loss due to water shortages caused by a damaged pipe or increased production costs due to health related absenteeism [29,49,63]. Because they have a straightforward and tangible effect on the economy and are mostly covered by private insurances, it is standard practice to assess direct economic impacts in the aftermath of natural disasters [4]. Indirect economic impacts are however more complex to capture. Hallegatte & Przulski [28] provide a few explanations for this shortcoming, among which the longer time span and larger spatial scale of indirect impacts or the fact that they vary across sectors and economic agents. Yet, in the long-run, indirect impacts add to total economic impacts of disasters to an extent that often exceeds direct physical damages [53,62]. Thus, capturing these indirect impacts is of prime importance to measure economic resilience in its entirety.

The literature on the assessment of indirect impacts and economic resilience of businesses is scarce. Hallegatte [26] developed an approach based on input-output tables to model economic impacts through input supply and demand variations across economic sectors, accounting for propagations and adaptive behaviors. Brozovic et al. [16] developed a methodology that consists in compiling sector specific (typology dependent) demand functions from different sources in order to assess the total costs of water lifeline interruptions following severe earthquakes in California both for business and residential water users. These approaches can be characterized as top-down or standardized normative approaches that disregard the particularities of individual businesses within a sector. As pointed out by Kajitani & Tatano [36], such classical estimations of economic damages to production losses account for restrictions of production capacity in an *ad hoc* manner but do not integrate vulnerability and resilience of businesses to assess production capacity losses, although Hallegatte [26] attempted to integrate adaptive behaviors in its approach. This is partly due to the lack of a common understanding of the multidimensional nature of economic resilience that differs from - but also encompasses aspects of - vulnerability and adaptation. Omitting that resilience is not only sector dependent but rather depend on individual characteristics that reflect the organization of the firm and affect its ability to recover from a shock leads to frequent misinterpretations.

This paper presents a complementary approach to standard, sector-typology based approaches described above in order to assess and investigate the processes and factors underlying individual economic resilience of businesses. Its ambition is to make the best use of the available theory in a very pragmatic goal: measuring and understanding the resilience of businesses in order to provide public policies with recommendations for building resilient economies. We first develop an explicit conceptual framework of the economic resilience of individual businesses that integrates and clarifies the relationships between resilience, adaptation and vulnerability. We then develop an aggregated indicator of economic resilience that addresses some of the current scientific and technical obstacles regarding the measurement of economic resilience at individual scale. The strength of our methodology lies in its ability to scientifically ground an operational measurement of microeconomic resilience that accounts for both the individual ability to cope with potential impacts and the timing of recovery. As an illustration, the indicator is then applied to businesses of the Urban Community of Central Martinique. Located in the French West Indies, this overseas territory encompasses many factors of vulnerability commonly censed in isolated islands [35,48]. Most of its infrastructures and activities are concentrated on the coastline which is subject to increasing natural hazards due to climate changes (e.g. erosion, submersion, rising sea-level) [31,50,68,69]. Moreover, insularity makes lifeline services particularly prone to cut-offs and outages, especially in the event of a natural disaster. As for economic impacts, they are likely to be significant because the economy of the French West Indies is mostly made of small businesses, often thinly capitalized and individually owned, that do not benefit from strong support functions to help

them anticipate and cope with potential impacts.

This research focuses on the microeconomic resilience of businesses to lifeline service interruptions, and as such, does not account for macroeconomic effects of natural disasters that pertain to the overall systemic resilience of the economy. However, the concepts and indicators produced may contribute to adapt production functions in macroeconomic models such as CGE models as suggested by Rose & Liao [53] who argue that classical models do not account for resilience and as such, tend to either overestimate (e.g. when adaptations are not accounted for), or underestimate (e.g. when a systematic return to equilibrium is considered after a long period of time), the effects of natural hazards on the economy. Concentrating on microeconomic processes allows our analysis to focus on the intrinsic ability of individual businesses to recover and adapt to a given degraded situation, disregarding the characteristics of the event that generates damages and indirect market effects such as dropping demand or increasing supply prices. It focuses on private businesses that are operated for profit, as opposed to public sector and non-profit organizations. This includes all types of business proprietorship, irrespective of their sector, size and turnover.

The present paper is organized as follows. We develop a conceptual framework for economic resilience and describe its theoretical foundations in Section 2. We then propose in Section 3 an original methodology to measure and assess the economic resilience of individual businesses. Results of the application of this indicator-based approach are presented in Section 4. In particular, the socio-economic drivers of economic resilience are investigated using a linear regression model. Section 5 discusses the interests and the limits of our methodology and Section 6 concludes by presenting a set of future perspectives to this work.

2. Conceptual framework for the economic resilience of individual businesses

Building on existing literature, we suggest a conceptual framework that highlights the composite nature of economic resilience at the microeconomic level (Fig. 1). This framework clarifies the relationships existing between vulnerability, adaptation and resilience. In doing so, it provides an analytical basis that is consistent with approaches developed in both risk and economic conceptual models [28,59,7].

2.1. Vulnerability

Natural disaster risks result from the interaction of (i) a hazard, that is the potential occurrence of a natural or human-induced physical event that may cause damage, harm or adverse effects, (ii) the exposure, that is the presence of stakes (e.g. people, assets, resources) in places and settings that could be adversely affected; and (iii) the vulnerability, which is the propensity or predisposition of individuals, communities and the environment to be adversely affected [35]. Focused on hazard as the triggering mechanism, vulnerability is commonly defined in the literature on disaster risks as the sensitivity of exposed elements to hazards [44] or as the degree to which a system is likely to experience damages due to its exposure to a hazard [67]. Social science literature offers a wider vision of the concept, including also non-hazard related forces (contextual parameters) influencing vulnerability [1,24,25,37]. The last IPCC report² recognizes vulnerability as a multidimensional propensity or predisposition that depends not only upon the character and intensity of the hazard to which a system is exposed, but also upon its lack of capacity to adapt, its sensitivity or susceptibility to harm, and its social, economic and

² The advances in conceptualizing vulnerability between IPCC's Third and Fifth Assessment Reports are a noteworthy evidence of the progress the scientific community achieved in understanding the complexity of this concept.

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