A look beyond climate risk exposure: the impact of incapacity to cope with natural hazards on financial development

Canh Phuc Nguyen

UEH University

Environmental Science and Pollution Research
https://doi.org/10.1007/s11356-023-26621-1

RESEARCH ARTICLE

A look beyond climate risk exposure: the impact of incapacity to cope with natural hazards on financial development

Canh Phuc Nguyen[1,2] · **Nguyen Duc Nguyen**[3] · **Jeff Wongchoti**[4]

Received: 1 February 2023 / Accepted: 20 March 2023

Abstract

We provide a comprehensive cross-country analysis on the impact of national incapacity to cope with natural hazards (i.e., social shocks, political stability, health care, infrastructure, and material security needed to reduce the harmful effects of natural disasters) on financial development. The panel quantile regression analyses on a global sample of 130 countries generally confirm that the financial development of countries with lower capacity to cope is indeed significantly hampered compared to their peers, especially in countries with low financial development levels. Seemingly unrelated regression (SUR) analyses, which acknowledge the dynamic co-existence between both financial institutions and financial market sectors in a given economy simultaneously, offer notable finer details. For example, the handicapping effect on both sectors tends to apply to only countries with higher climate risks. Lack of coping capacity also exert negative effects on the development of financial institutions in countries of all levels of income but only affect financial markets of high-income group. The more detailed look into different dimensions (financial efficiency, financial access, and financial depth) of financial development is also given in our study. Overall, our findings highlight the vital and complex role of "coping capacity" aspect of climate risk on the sustainable development of financial sectors.

Keywords Climate risk · Financial development · Coping capacities · Financial institutions · Financial market

Introduction

There is a growing literature that indicates climate change as an emerging financial risk and expansively examines its impact on wide-ranging aspects of financial economics. However, the more "in-control-by-human factor" angle of the issue regarding the readiness to cope with such clear and present danger has been relatively less emphasized. We argue that there is a need to look beyond the likelihoods (e.g., exposures) of experiencing climate change events themselves. While such occurrences have become more frequent in the recent years, their impacts may be only short run. Attention to this point is still very limited in the literature. As an example, Klomp (2016) shows that natural disasters appear to reduce overall economic development but this effect is rather short-lived. To the extent that climate changes themselves are not entirely predictable (and yet systematic and can cause hesitations among economic agents in each economy from time to time), the most rational way for a nation to deal with it is to build up the coping capacity to natural hazards. In this way, long-term confidence towards weathering climate changes can be restored. The higher exposure to climate risk, the more damaging to economic agents' confidence in response to the lack of capacity to cope with such events. In this study, we provide the first comprehensive analysis on the impact of national incapacity to cope with natural hazards on its financial development.

Responsible Editor: Nicholas Apergis

✉ Canh Phuc Nguyen
canhnguyen@ueh.edu.vn

[1] School of Public Finance, College of Economics, Law and Government, University of Economics Ho Chi Minh City, 59C Nguyen Dinh Chieu, District 3, Ho Chi Minh City 700000, Vietnam

[2] Health and Agricultural Policy Research Institute, College of Economics, Law and Government, University of Economics Ho Chi Minh City, Ho Chi Minh City 700000, Vietnam

[3] UEH-International School of Business, University of Economics Ho Chi Minh City, Ho Chi Minh City, Vietnam

[4] School of Economics and Finance, Massey University, Palmerston North, New Zealand

Published online: 28 March 2023

The development of financial sector has long been recognized as a crucial driver of economic development (see, e.g., Levine 1999; Beck et al. 2000; Levine and Zervos 1996, among others). In extension, financial development can also exert significant repercussions on various dimensions of development such as social issues (Chiu and Lee 2019; Bittencourt et al. 2019; Altunbaş and Thornton 2019) and environmental problems (Yao et al. 2021; Usman et al. 2021; Nguyen et al. 2021; Nasir et al. 2021). Hence, understanding the determinants of financial development is widely important for both scholars and policymakers.

However, in studying financial development, it is essential to acknowledge both Financial institutions and financial markets in the same framework as they all matter to the optimal allocation of wealth for economic agents in a nation. Due to data limitation, most previous studies are forced to employ simply proxy such as market size of stock market or credit market (Voghouei et al. 2011) as the indicators of financial development or they are investigated separately altogether (Law and Habibullah 2009). Until recently, the introduction of a new broad-based index of financial development by Svirydzenka (2016) has allowed researchers to 'more comprehensively' study this variable. In the same vein as more recent studies that investigate the determinants of financial development, our dependent variables are largely based on the special data provided by Svirydzenka (2016).

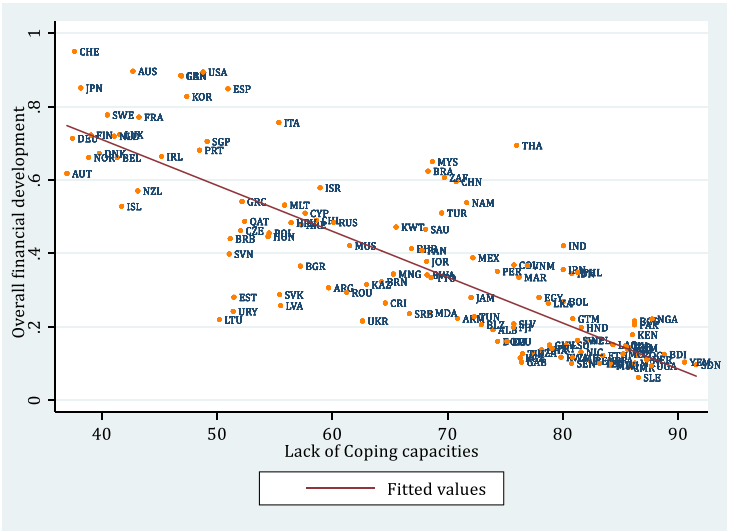
Another uniqueness of the above financial development data is that it allows researchers to consider the multi-dimensions of financial development, and in both financial sectors (financial institutions versus financial markets). Several recent studies have shown that different dimensions of financial institutions or financial markets would develop varying across countries (Phuc Nguyen et al. 2020). These dimensions are (1) financial access, (2) financial efficiency, and (3) financial depth and they would have different roles in socio-economic-environmental development (Nguyen and Su 2021a, b; Le et al. 2020; Canh and Thanh 2020). Financial access refers to the ease and ability of individuals and corporations in an economy to gain access to financial services and transactions in either financial sector (institutions and markets). Financial efficiency is tricky in the perspectives of financial institutions versus financial markets. For institutions, efficiency means "cost" efficiency and thus profitability of banks operated in an economy. It ensures the survival of financial institutions who perform the duty of money lending function to the society. On the other hand, efficiency in the financial market refers to "information" efficiency whereby transactions in these markets would be fair and timely, leading to the continuity and survival of these markets in the long run. Lastly, financial depth can be described as the volume (size) of financial sectors in comparison to a nation's economic output. It thus indicates how broad the financial sector can cater economic agents relatively to how productive they are. Our study thus shed further light on climate risk literature by analyzing the influence of coping incapacity to climate changes on all of these important dimensions within the financial development of a nation.

The climate risk is recognized as one of the most challenging issues in our time (Eckstein et al. 2021; Hong et al. 2019; Zscheischler et al. 2018; Challinor et al. 2017). There are several severe socio-economic consequences of extreme natural events (Panwar and Sen 2019; Kapucu and Liou 2014; Noy 2009). For instance, Noy (2009) suggest that natural disasters could lead to slowdowns in production and output. Similarly, Panwar and Sen (2019) conclude that natural disasters exert severely negative impacts on economic development of 102 countries from 1981 to 2015. These consequences of climate risk would imply the decreases in demand side of financial sectors. Moreover, the increases in climate risk would imply the increases in systematic risk for activities of financial sectors (Phillips et al. 2020; Chen and Silva Gao 2012; Charpentier 2008). Thus, it may lead to risk aversion of financial sectors (Bourdeau-Brien and Kryzanowski 2020). Overall, both demand and supply side of financial sector may be negatively impacted by the climate risk. However, as Klomp (2016) remarks, the adverse economic impact of natural disaster events themselves could only short run.

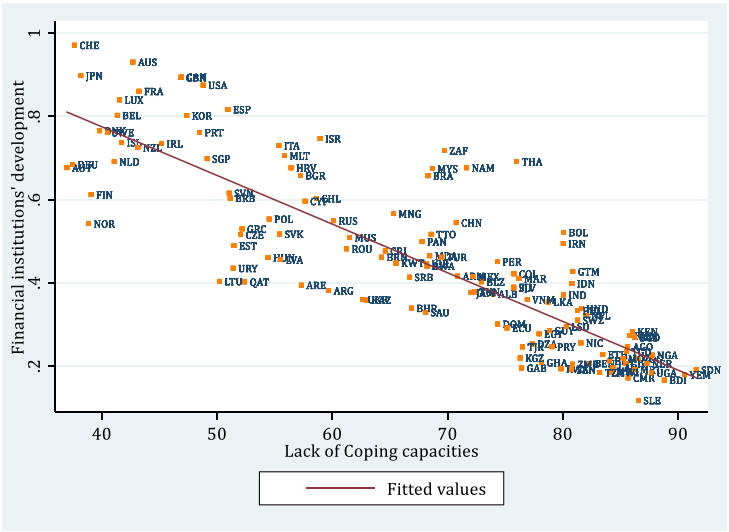
As discussed in Hilft (2020), the emergence of a disaster do not solely depend solely on its severity or the size of the effects it bear. Indeed, how vulnerable the society is impacted by the influences of that natural disaster can also indicate the climate risk. One of the facets that attract considerable attention from scholars is the ability and resource needed to reduce possible consequences of disruptions originated from such hazardous events (Sorg et al. 2018; Birkmann adn Welle, 2015). We argue that the lack of capacity to cope with natural disaster events could be more important in the minds of rational economic agents in the long run. This is in line with the more recent view regarding proactive approach in dealing with climate risk among corporations (Elijido-Ten and Clarkson 2019).

Figure 1 preliminarily shows that the lack of coping capacities seems to be strongly associated with inferior overall financial development, and in both financial institution and financial market sectors. In other words, the actions of governments in preparing to face climate risk might be more important for financial system than the status of exposing to natural climate. Japan is an interesting example that highlights our argument.[1] For instance, the nation has experienced numerous natural disasters (earthquakes, among

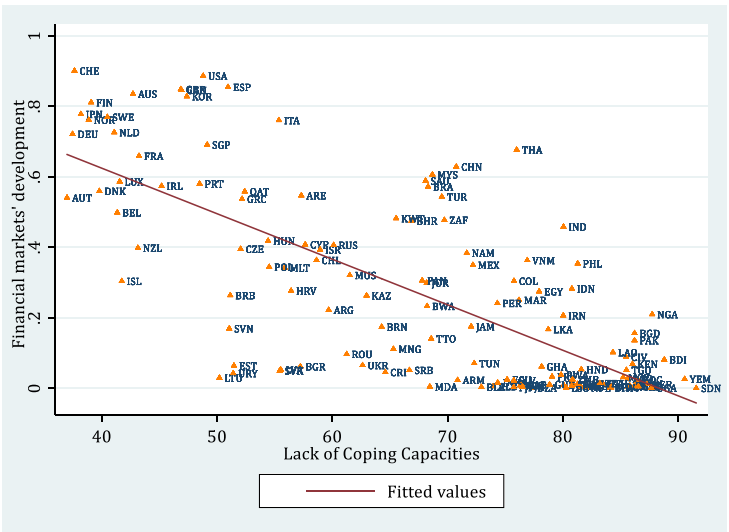
[1] We thank an anonymous referee for pointing this out.



a) Lack of Coping capacities to natural hazards and overall financial development



b) Lack of Coping capacities to natural hazards and development of financial institutions



c) Lack of Coping capacities to natural hazards and development of financial markets

Fig. 1 Lack of coping capacities to natural hazards and financial development. **a**) Lack of coping capacities to natural hazards and overall financial development. **b**) Lack of coping capacities to natural hazards and development of financial institutions. **c**) Lack of coping capacities to natural hazards and development of financial markets

others) throughout its history. At the same time, she has displayed superior capacity and readiness to cope with such hazards.[2] As a result, Japan is listed in the top tier group of nations regarding financial development, relative to countries around the globe. Remarkably, the impact of coping (proactive) side of climate risk on financial development is not studied in the literature and we intend to fill the gap.

To comprehensively investigate the influences of coping incapacity on climate risk on multidimensional financial development and among countries with different levels of financial development, we employ panel quintile regression analysis. This is necessary as existing literature indicates that the consequences of natural disasters could vary across different levels of economic development (Panwar and Sen 2019; Klomp 2016; Kron 2000). Specifically, developing nations are also more vulnerable to natural risk than advanced counterparts. Meanwhile, the financial sectors in developing countries are properly less developed and less regulated in general (Anginer et al. 2019a, b; Karwowski and Stockhammer 2017). They are also known for more risk-seeking activities (Moudud-Ul-Huq et al. 2018; Wu et al. 2017). As such, the influences of coping incapacity to climate risk on financial development may be heterogeneous and influenced by outliers (and non-linearity in the relation between dependent and independent variables) across countries.

In addition, to investigate simultaneously the effects of national coping incapacity on the multidimensional financial development (as mentioned earlier), we apply seemingly unrelated regression (SUR) technique. This is different from previous studies in the field that have investigated the determinants of financial institutions or financial markets and their dimensions separately. SUR is aimed to account for the shared unobservables among the two sectors and various dimensions (of financial development) accordingly. This also facilitates us to contrast between different subsamples based on national exposures to climate risks and the countries' income levels.

With the full sample of 130 countries covering the 2011–2019 period, highlighted findings are presented as follows. First, consistent with our conjecture, the panel quintile regression analyses broadly confirm that the financial development of countries with lower capacity to cope with natural hazards is indeed significantly worse in comparison. This is especially true in countries with lower financial development levels. By acknowledging the dynamic co-existence between both financial institutions and financial market sectors in a given economy simultaneously, results from SUR offer several further details of such relation. For example, it is rational to observe that the harming effect on financial development of both sectors tends to apply to only countries with higher climate risks (where coping capacity is needed most). Lack of coping capacity also exerts negative effects on the development of financial institutions in countries of all levels of income but only affects financial markets of high-income group (where participations in financial markets may be more active to begin with but harmed by the sense of vulnerability due to lack of coping capacity to natural hazards). Across different dimensions (financial efficiency, financial access, and financial depth) of financial development, lack of coping capacities only impounds significant negative impacts on the "access" to financial institutions. It has no significant impact on financial institutions' depth. Interestingly, however, coping incapacity enhances financial efficiency of financial institutions. In other words, it is possible that lack of capacity to cope with natural hazards in the national level is exploited by financial intermediaries as an excuse to charge more to the financial service consumers (and thus provide them with higher profitability). This is different from the financial markets as all three dimensions of financial development suffer from coping incapacity. Overall, our findings confirm the negative impact of coping incapacity on financial development but yet imply asymmetric effects of inability to cope with climate risks on the development of different financial sectors. Our study thus highlights the needs for specific and articulated policies in developing sustainable financial sectors, in the presence of climate changes, around the globe.

The study is structured as follow. The next section reviews the literature review. The empirical model, data, and panel estimates are explained in "Empirical model, data, and estimates." "Results and discussions" presents the results and discussion. The final section concludes.

Literature review

Determinants of financial development

Optimally allocating wealth (in the presence of uncertainties) among economic agents in a given economy is a challenging task. Due to the paramount importance of the financial system in economic-socio-environmental development (including sustainability—see, e.g., Usman et al. 2021; Nguyen and Lee 2021; Nguyen et al. 2021; Busch et al. 2016), there have been burgeoning studies exploring determinants of financial development. Huang (2010) and Voghouei et al. (2011) summarize four main drivers of financial development, namely institutions, macro policies, geography, and other features.

[2] The World Economic Forum indicates Japan's ability to cope with natural disasters. See: https://www.weforum.org/agenda/2022/11/cop27-how-japan-is-using-tech-mitigate-natural-disasters/.

In the first strand of literature, the effects of institutions on financial development have been considerably investigated through the roles of legal and regulatory systems (see La Porta et al. 1997; Acemoglu et al. 2001; Beck et al. 2003, among influential studies). The legal and regulatory systems related to information disclosure, accounting standards, financial practices would play important roles in protecting creditors, shareholders, and borrowers. Thus, institutional characteristics are emphasized as the foundation of the development of financial sectors (Huang 2010). Khan et al. (2019) show that institutional quality is a significant driver of financial development in the USA over the period of 1984–2016. Law and Azman-Saini (2012) find that institutional environment is positively associated with the banking sector development, while it links with stock market development in a non-linear manner.

The second strand of literature highlights the importance of macroeconomic policies, economic openness, and financial liberalization in financial development (Chinn and Ito 2006; Do and Levchenko 2004; Boyd et al. 2001; Huybens and Smith 1999). Prior studies explain that macroeconomic policies would either boost or constrain financial development through the demand and supply side. For example, a prudent policy to keep low inflation would be a good environment for financial development (Boyd et al. 2001; Huybens and Smith 1999), while policies to open the economy and financial liberalization would also stimulate financial development attributable to the increases of investment and productivity (Kim et al. 2010; Do and Levchenko 2004; Bekaert et al. 2002).

The third strand of theories and empirics points out that geographic features (e.g., latitude, natural barriers, and resource endowment) might influence financial development through their association with economic development. Specifically, existing literature indicates that latitude would link with productivity of cropping and production (Gallup et al. 1999) and the quality of environment (Acemoglu et al. 2001). Natural barriers associated with the geographic location of a country, such as the distance from large markets, would determine its capability in integrating into international trade and absorbing knowledge (Malik and Temple 2009; Easterly and Levine 2003). Moreover, natural resource endowment is essential for a country since it drives export structure, institutional capacities, and economic development (Easterly and Levine 2003).

At last, Huang (2010), among others, indicates "other potential" determinants of financial development including income level, economic growth, population, religions, language, and ethnic. In which, income level is positively linked with financial development (Jaffee and Levonian 2001). Another exotic variable is difference in cultures (religions, language, ethnic) as they could account for the differences in the process of financial development. Differences in social norms and beliefs of people in economic and financial activities emerge as a result (Stulz and Williamson 2003). In addition, Ashraf (2018) find that trade openness would promote development of banking system when using a sample of 37 emerging countries from 2000 to 2012. Zhang et al. (2015) add that in addition to trade openness, financial openness matters for financial development in China. Ang (2019) reveals that culture factor (cultural orientation toward individualism) can drive financial development in a sample of 97 countries. Recently, Phuc Canh and Trung Thong (2020) confirm long-run mutual relationships between natural resources rents and financial development in a sample of 86 economies from 2002 to 2017. Hafer (2016) suggests that average intelligence level of a country has a linkage with financial development since individuals with higher levels of intelligence might save more. Mlachila and Ouedraogo (2019) add that shocks in commodity prices can alter the development of financial system in commodity-rich countries. Or, Cheng et al. (2021) consider the interlinks between financial development with information technology and economic growth.

The economic role of climate concerns

In the context of climate change and global warming, Busch et al. (2016) emphasize that financial system has witnessed the shifts in its activities and the linkages with overall development, especially on sustainable development. Pioneering financial institutions tend to develop financial innovations to support sustainable development (Peeters 2005). As an example, actors in the financial sector such as banks with the engagement into environmental issues seem to have less overall risk (Gangi et al. 2019). Meanwhile, the Intergovernmental Panel on Climate Change (IPCC) has issued a warning about the rising of several extreme natural hazard events such as heatwaves, flooding, storms across the globe as the consequences of climate change (IPCC 2021). Some studies in literature reveal that climate risk is one of the greatest risk of our time (Challinor et al. 2017; Urban 2015). The climate change and climate risk would exert systematic effects on all economic sectors from growth (Zhang and Managi 2020), consumption (Nguyen 2022a, b), agricultural activities (Fuhrer et al. 2006), production (Nguyen 2022a, b), economic development (Asyahid and Pekerti 2022; Wu and Guo 2021; Klomp 2016), poverty and income inequality (Millner 2013; Barrett et al. 2007), or even institutional frameworks (Ghimire 2021).

Existing literature seems to focus on the influences of climate risk on players in the financial systems. For instance, focusing on insurance market in 39 countries from 1984 to 2009, Chang and Berdiev (2013) conclude that the incidences of natural disasters and its death repercussion would lead to an increase in insurance consumption. As for

commercial banks, Klomp (2014) add that natural disasters increase the default probability of commercial banks across 160 countries from 1997 to 2010. Berg and Schrader (2012) find that while credit need increases after a volcanic activity, "access" to credit from banks is reduced. Recently, Do et al. (2022) emphasize that natural disasters reduce bank stability in a sample of 907 domestic/local US banks from 2010 to 2019. They explain that natural disasters magnify volatility in deposit and defaults. To cope with these climate-induced risks, banks become more cautious and respond by increasing lending margins and loan loss provision.

We note that the above studies limit their scope to only one aspect/dimension of a financial sector in each economy. Svirydzenka (2016) emphasize that financial system has a complex multidimensional nature, whereas a simply indicator such as private credit cannot reflect the overall picture clearly. Following the important initiations by Čihák et al. (2012) and Sahay et al. (2015), the multidimensional financial development indicators including two sub-sectors (financial institutions and financial markets) and three dimensions (financial access, financial efficiency, financial depth) are introduced by Svirydzenka (2016) for a global sample of 183 countries from 1980s. Subsequently, there is a rising attention and works regarding multidimensional financial development and its relationships with economic-socio-environmental factors (e.g., see Nguyen et al. 2021; Nguyen and Su 2021a, b and others). In this vein, Phuc Nguyen et al. (2020) is among few studies focusing on the determinants of financial development. They document that internet usage and mobile usage have positive effects on multidimensional financial development in a sample of 109 economies from 1998 to 2017.

Studies on the impacts of natural disasters on financial development are still quite limited in the literature. They also rather focus on the events themselves. Observing 42 severe extreme weather events (storms, floods, cyclones, earthquakes, and bushfires) and the Australian equity market, Worthington and Valadkhani (2004) conclude the financial impacts on financial market in response to these events are not universal, as they may exert positive and/or negative on market returns on the day of the event. As for financial institution sector, Collier and Skees (2012) report an interesting fact in the case of Peru financial intermediaries where they do use insurance against El Niño to protect themselves from natural disaster risk. Using private credit as a simple proxy of financial development, Keerthiratne and Tol (2017) find that natural disasters seem to increase private credit in a sample of 147 countries over the period of 1979–2011.

However, as noted by Klomp (2016) that the economic impact of certain climate events themselves could be short-lived, the real implication of climate "risk" in the longer term should be the readiness to cope with such events if they were to take place (and they will). How vulnerable a financial system (both financial institutions and financial markets) is to climate risk is thus largely dependent on the national capacity to cope with climate situations, not just the likelihood of extreme natural events alone. This is largely missing in the literature but consistent with the views regarding risk/uncertainty. Specifically, uncertainty is a situation with no information of probability (Lawson 1985). Recent development of literature shows that uncertainty (i.e., economic uncertainty or economic policy uncertainty) plays important roles in explaining economic activities (Nguyen and Su 2021c; Colombo 2013; Bloom 2009). The literature shows that increases in uncertainty appear to reduce investment (Bloom 2009; Bloom et al. 2007) and consumption (Mumtaz and Surico 2018; Bertola et al. 2005), thus causes downfall of output (Cesa-Bianchi et al. 2019; Mumtaz and Surico 2018) and employment (Schaal 2017; Caggiano et al. 2017, 2014; Choi and Loungani 2015). As such, we conjecture the increases of climate risk (due to the lack of coping capacity within a nation) may negatively affect financial development from both demand and supply side.

On the supply side, at least, the climate risk is a kind of systematic risk for the whole economy. Li et al. (2021) explain that climate risk is induced by climate "change" along with the complex connections among socio-economic systems. Climate risk, on the other hand, could be a holistic risk originated from the interaction, interconnection, and evolutions of several risks. As such, increases in climate risk with the nature of risk and uncertainty would expect to exert negative impacts on economic activities, especially long-term economic growth (Mendelsohn 2009). Previous studies (Bowen et al. 2012; Dell et al. 2009, 2008) indicate that climate risk would reduce economic growth significantly. With the increasing risk and uncertainty due to climate risk and the future growth prospect, financial system may respond rationally by reducing their risky activities such as credit supply or investment activities. For instance, Brei et al. (2019) reveal that after a hurricane strike into the Eastern Caribbean, local banks witnessed deposit withdrawals and, immediately reduce credit supply. On the demand side, the increases of climate risk might also exert significant negative impacts. Increases in climate risk with the nature of risk and uncertainty would reduce economic activities, unemployment, consumption, and investment of economic agents. Recent studies emphasize that climate risk is not only investment risk (Scanlan 2021) but also financial risk (Wagner 2022; Rudebusch 2021). The increases of climate risk might stimulate economic agents increasing savings rather than investments (Huang and Wu 2018). Economic agents are usually more prone in investments (Hosono et al. 2016).

Our argument to focus on the implication of coping capacity and not just the climate change exposure

itself is also consistent with the emerging view regarding sustainability. Financial sector itself has evolved as a crucial factor for sustainability for a nation (Jeucken 2010). There have also been several innovations to support sustainable developments from financial systems (Cortellini and Panetta 2021). Krueger et al. (2020) report an interesting perception of institutional investors that they consider risk management or engagement rather than divestment when dealing with climate risk. In other words, finance professionals operating in financial sectors display their preference towards proactive approaches when it comes to managing climate risk. On the one hand, financial sectors may follow their own risk management around climate changes and engagement to diversify their activities, especially in supplying fund and financial services. However, such resiliency of a financial system can only sustain through the boosting of confidence on the factor that is beyond the control by actors in the financial sector. The less-studied coping incapacity on natural hazards on the country level is thus the main explanatory variable in our study.

Empirical model, data, and estimates

Empirical model

To examine the influences of climate risk on multidimensional financial development, this study bases on the extent literature of financial development (see Levine 1999, Levine et al. 2000, Huang 2010, and Voghouei et al. 2011) to form the baseline model as follow:

$$\begin{aligned}\mathrm{MFD}_{it} &= \beta_0 + \beta_1 \mathrm{Institution}_{it} + \beta_2 \mathrm{Income}_{it} \\ &+ \beta_3 \mathrm{Trade}_{it} + \beta_4 \mathrm{HC}_{it} + \gamma_i + \delta_t + \varepsilon_{it}\end{aligned} \tag{1}$$

where β are coefficient; I and t denote country i at year t; γ, δ are country-fixed and time-fixed effect, respectively; ε is error terms; *Institution*, *Income*, *Trade*, and *HC* denote for institutions, economic development, trade openness, and human capital, respectively.

The dependent variable, MFD_{it}, represents multidimensional financial development.

As noted in Huang (2010) and Voghouei et al. (2011), institutional frameworks in the model of financial development include formal and informal institutions. In this study, formal institutions are represented by institutional quality (Inst) measured through the Worldwide Governance Indicators (World Bank). Meanwhile, informal institutions are measured through four dimensions: colonial history (Colony), socialist history (Socialist), civil law system (Civil law), religion characteristics (Religion), and language characteristics (Language) (see La Porta et al. 1997; Acemoglu et al. 2001; Beck et al. 2003). The detail of Eq. (1) is as follow:

$$\begin{aligned}\mathrm{MFD}_{it} =& \beta_0 + \beta_{11}\mathrm{Inst}_{it} + \beta_{12}\mathrm{Colony}_{it} + \beta_{13}\mathrm{Socialist}_{it} + \beta_{14}\mathrm{Civill\ aw}_{it} \\ &+ \beta_{15}\mathrm{Religion}_{it} + \beta_{16}\mathrm{Language}_{it} + \\ &\beta_2\mathrm{Income}_{it} + \beta_3\mathrm{Trade}_{it} + \beta_4\mathrm{HC}_{it} + \gamma_i + \delta_t + \varepsilon_{it}\end{aligned} \tag{2}$$

Following recent studies document that urbanization (Urban) and Internet usage (Internet) (Phuc Nguyen et al. 2020) are also potential determinants of financial development, we include these variables as additional control variables:

$$\begin{aligned}MFD_{it} =& \beta_0 + \beta_{11}\mathrm{Inst}_{it} + \beta_{12}\mathrm{Colony}_{it} + \beta_{13}\mathrm{Socialist}_{it} \\ &+ \beta_{14}\mathrm{Civil\ law}_{it} + \beta_{15}\mathrm{Religion}_{it} + \beta_{16}\mathrm{Language}_{it} \\ &+ \beta_2\mathrm{Income}_{it} + \beta_3\mathrm{Trade}_{it} + \beta_4\mathrm{HC}_{it} \\ &+ \beta_5\mathrm{Urban}_{it} + \beta_6\mathrm{Internet}_{it} + \gamma_i + \delta_t + \varepsilon_{it}\end{aligned} \tag{3}$$

At last, we add climate risk (cRisk) as augmented driver of multidimensional financial development:

$$\begin{aligned}\mathrm{MFD}_{it} =& \beta_0 + \beta_{11}\mathrm{Inst}_{it} + \beta_{12}\mathrm{Colony}_{it} + \beta_{13}\mathrm{Socialist}_{it} \\ &+ \beta_{14}\mathrm{Civil\ law}_{it} + \beta_{15}\mathrm{Religion}_{it} + \beta_{16}\mathrm{Language}_{it} \\ &+ \beta_2\mathrm{Income}_{it} + \beta_3\mathrm{Trade}_{it} + \beta_4\mathrm{HC}_{it} \\ &+ \beta_5\mathrm{Urban}_{it} + \beta_6\mathrm{Internet}_{it} + \beta_7\mathrm{CRisk}_{it} + \gamma_i + \delta_t + \varepsilon_{it}\end{aligned} \tag{4}$$

Data

We collect the research data from multiple sources. In term of multidimensional financial development, we collect data from the financial development database provided by the International Monetary Fund (IMF), which is measured by Svirydzenka (2016). In this database, in addition to the overall financial development, there are two sub-sectors of financial system: financial institutions and financial markets. In each sub-sector, there are three dimensions: (i) financial efficiency, (ii) financial access, and (iii) financial depth.

As such, we have ten indicators: overall financial development (FD), development of financial institutions (FI), development of financial markets (FM), financial institutions efficiency (FIE), financial institutions access (FIA), financial institutions depth (FID), financial markets efficiency (FME), financial markets access (FMA), and financial markets depth (FMD).

In term of climate risk, this study collects the lack of coping capacities to natural hazards index (lCop) from the World Risk Reports—(WRR) prepared by Hilft (2020).[3] WRR provides information of the climate risk for over 170 countries from 2011 toward five important natural hazards: earthquakes, floods, storms, sea-level rise, and droughts. lCop indicates the insufficiency of health care systems, good

[3] Full reports from 2011 to 2020 can be downloaded from here https://weltrisikobericht.de/weltrisikobericht-2020e-neu/#downloads.

governance, and social and material security. These are vital infrastructures and tools for a country to cope with natural hazards. This variable, lCop is utilized in recent studies targeting the risk assessment of climate-related hazards such as Birkmann and Welle (2015) and Sorg et al. (2018).

The above database is currently among the most comprehensive dataset of climate risk for global sample. We also collect the exposure to natural hazards index (Exp) to represent for the levels of climate risk in each country, which would help us to evaluate the influence of lack of coping capacities on financial development by different levels of climate risk.

In term of control variables, we collect data from different sources. Six institutional indicators (control of corruption, rule of law, regulatory quality, voice and accountability, political stability and absence of violence, and government effectiveness) are collected from the Worldwide Governance Indicators (WGI). The mean value of six denoted indicators is used to proxy for the overall formal institutional quality.

Following relevant studies on the determinants of financial development (e.g., Reynolds and Flores 1989; La Porta et al. 1999; Acemoglu et al. 2001; Bertocchi and Canova 2002), we employ five dummy variables to proxy for informal institutions as follows:

(i) The dummy colonial history variable *(*Colony) which equals one if country has a colonial history during the nineteenth and twentieth centuries, otherwise it equals zero
(ii) The dummy socialist history variable (Socialist) which equals one if country was a socialist country or they are currently socialist countries, otherwise it equals zero
(iii) The dummy variable of origin of the legal system (Civil law) which equals one if country has the civil law system, otherwise it equals zero
(iv) The dummy religion variable (Religion) which equals one if country has only one dominant religion (religion with over 50% of population as its followers), otherwise it equals zero; and
(v) The dummy variable of language (Language) which equals one if country has only one official language, otherwise it equals zero. To define these above dummy variables, we base on information from the World Factbook of the CI.[4]

Regarding other explanatory variables, real GDP per capita (in natural logarithm), urban population (% of total population), trade (as a percentage of GDP), and percentage of individuals using the Internet are recruited from the World Development Indicators (WDI—World Bank) to proxy for economic development, urbanization, trade openness, and Internet usage, respectively. The human capital is proxied by the human capital index (in log form) from the Penn World Table version 10.0 (PWT) (Feenstra et al. 2015).

Since the data of climate risk from WRR is available from 2011, while the data of multidimensional financial development from IMF is available until 2019, the period of 2011–2019 is thus chosen as our period of the study. The choice of this period until 2019 also allows us to exclude the period of 2020 and 2021, whereas the COVID pandemic has caused serious challenges for the economy and financial sector (Matos et al. 2021).

After collecting and matching all variables, we remove countries with missing data in climate risk or multidimensional financial development. The final sample includes 130 countries (see Table A1, Appendix, for the details of countries in our sample). Details of variables, calculations, definitions, sources, and data description are presented in Table 1.

Panel estimates

In estimating the influence of climate risk on multidimensional financial development using panel data, the problem of heteroscedasticity should be taken into account (Stock and Watson 2008). There are different development levels across countries (Karwowski and Stockhammer 2017). Previous studies indicate that there are differences in financial systems across countries originated from differences in regulations (Anginer et al. 2019a, b) or risk-taking behaviors (Bai et al. 2020; Moudud-Ul-Huq et al. 2018). Hence, the influences of climate risk on financial development might be heteroscedastic across levels of financial development.

In order to take into account of heteroscedasticity, the study recruits the panel quantile regression with fixed effects proposed by Powell (2022) to examine the influences of climate risk on different quantiles of overall financial development. Koenker and Bassett (1978) suggest that the panel quantile regression would be superior than the ordinary least square estimate since it helps to estimate the influence by conditional quantile of the dependent variable (financial development). Hao and Naiman (2007) further add that the quantile regression could deal with issue of heterogeneity and even outliers. This study follows Powell (2022) to using the Markov chain Monte Carlo method in running panel quantile regression with fixed effects. The application of fixed effect in panel quantile regression also helps to account for time-fixed and country-fixed effects (γ_i and δ_t in above eqs. 1 to 4).

Next, to estimate the influences of incapacity to cope with natural hazards on two sub-sectors of financial development (financial institutions and financial markets), this study conducts a more comprehensive analysis than previous studies. In fact, most previous studies (references) examine the

[4] Central Intelligence Agency.

Table 1 Variables, definitions, calculations, sources, and data description

Variable	Definition	Calculation	Source	Obs	Mean	S.D	Min	Max
FD	Overall financial development	Financial development index	IMF	1170	0.368	0.236	0.046	0.983
FI	Financial institutions' development	Financial institutions index	IMF	1170	0.454	0.214	0.084	1.000
FM	Financial markets' development	Financial markets index	IMF	1170	0.271	0.275	0.000	0.965
FID	Financial institutions depth	Financial institutions depth index	IMF	1170	0.317	0.276	0.016	1.000
FIA	Financial institutions access	Financial institutions access index	IMF	1170	0.395	0.270	0.000	1.000
FIE	Financial institutions efficiency	Financial institutions efficiency index	IMF	1170	0.603	0.111	0.187	0.835
FMD	Financial markets depth	Financial markets depth index	IMF	1170	0.280	0.301	0.001	1.000
FMA	Financial markets access	Financial markets access index	IMF	1170	0.275	0.295	0.000	1.000
FME	Financial markets efficiency	Financial markets efficiency index	IMF	1170	0.246	0.343	0.000	1.000
Exp	Exposure to climate risk	Exposure to natural hazards index	WRR	1170	14.73	8.631	0.050	57.62
LCop	Lack of coping capacities to climate risk	Lack of coping capacities index	WRR	1170	67.40	15.57	35.16	94.14
Inst	Overall formal institutional quality	Average of six institutional indicators	WGI	1170	0.100	0.863	-2.000	1.873
Income	Economic development level	Real GDP per capita (in log form)	WDI	1170	8.792	1.422	5.628	11.60
Internet	Information technology development	Individuals using the Internet (% of population)	WDI	1170	49.89	30.12	0.000	99.70
Trade	Economic openness	Trade (% GDP)	WDI	1170	84.47	55.19	0.000	380.1
HC	Human capital accumulation	Human capital index (in log form)	PWT	1170	0.944	0.284	0.160	1.471
Urban	Urbanization	Urban population (% of total population)	WDI	1170	60.47	22.61	10.92	100.0
Colony	Colonial history	Dummy variable, equals 1 if country has colonial history, otherwise equals 0		1170	0.546	0.498	0.000	1.000
Socialist	Socialist history	Dummy variable, equals 1 if country has socialist history or a current socialist, otherwise equals 0		1170	0.469	0.499	0.000	1.000
Civilaw	Civil law system	Dummy variable, equals 1 if country has the origin civil law system, otherwise equals 0		1170	0.523	0.500	0.000	1.000
Religion	One dominant religion	Dummy variable, equals 1 if country has one dominant religion that accounts for more than 50% of population, otherwise equals 0		1170	0.708	0.455	0.000	1.000
Language	One official language	Dummy variable, equals 1 if country has one official language, otherwise equals 0		1170	0.723	0.448	0.000	1.000

The data of financial development is collected from the financial development database from IMF, which is calculated by Svirydzenka (2016)

WRR is the WorldRiskReports by Bündnis Entwicklung Hilft (www.WorldRiskReport.org)

WGI is Worldwide Governance Indicators of World Bank (see https://info.worldbank.org/governance/wgi/)

WDI is World Development Indicators of World Bank (see https://databank.worldbank.org/source/world-development-indicators)

PWT is the Penn World Tables version 10.0 (https://www.rug.nl/ggdc/productivity/pwt/?lang=en)

Other data of informal institutions are collaborated by authors from previous studies:

○ Colonial history is defined as Yes if this country used to be colonized by the UK, or Spanish, or Portugal in nineteenth or twentieth century following ideas of Bertocchi and Canova (2002). Data is collected from Bertocchi and Canova (2002) and our collaboration

○ Socialist is country who used or is currently Socialist. Data is formed by our elaboration

○ Law systems are defined by the origin of their law systems following civil law or others (common law, Islam law, or others), the law system classification is followed the idea of La Porta et al. (1999) and some data is collected from Reynolds and Flores (1989), remained data is manual collected from the World Factbook of Central Intelligence Agency (CIA) (see https://www.cia.gov/library/publications/the-world-factbook/fields/308.html)

○ Dominant religion is defined by the religion that has more than 50% of population as followers. The religion is followed the ideas of Cheibub et al. (2010) and Cooray and Potrafke (2011) and the data is manual collected from the World Factbook of CIA (see https://www.cia.gov/library/publications/the-world-factbook/fields/401.html#XX)

○ Official language is defined from data of World Factbook of CIA

determinants of financial institutions and financial markets, separately. However, it is important to notice that the two sub-sectors have inter-connections. Moreover, climate risk appears to be a common risk for both sub-sectors. As such, this study would simultaneously estimate the influences of coping incapacity on financial institutions and financial markets through the system equation below:

In order to estimate the system Eq. (5), this study employs the seemingly unrelated regression (SUR) technique by Zellner (1962). We employ SUR estimate since there are related services and competition between the two financial sectors, namely financial institutions (e.g., banks) and financial markets (e.g., stock markets). In addition, economic agents might also use services from both sub-sectors for their needs. As such, two sub-sectors would be related and the error terms in their equations in system Eq. (5) are possibly correlated. In this case, the SUR estimate is indicated as the most appropriate estimations.

$$\begin{cases} \mathrm{FI}_{it} = \beta_0 + \beta_{11}\mathrm{Inst}_{it} + \beta_{12}\mathrm{Colony}_{it} + \beta_{13}\mathrm{Socialist}_{it} + \beta_{14}\mathrm{Civillaw}_{it} + \\ \quad +\beta_{15}\mathrm{Religion}_{it} + \beta_{16}\mathrm{Language}_{it} + \beta_2\mathrm{Income}_{it} + \beta_3\mathrm{Trade}_{it} + \\ \quad +\beta_4\mathrm{HC}_{it} + \beta_5\mathrm{Urban}_{it} + \beta_6\mathrm{Internet}_{it} + \beta_7\mathrm{CRisk}_{it} + \gamma_i + \delta_t + \varepsilon_{it} \\ \mathrm{FM}_{it} = \beta_0' + \beta_{11}'\mathrm{Inst}_{it} + \beta_{12}'\mathrm{Colony}_{it} + \beta_{13}'\mathrm{Socialist}_{it} + \beta_{14}'\mathrm{Civillaw}_{it} + \\ \quad +\beta_{15}'\mathrm{Religion}_{it} + \beta_{16}'\mathrm{Language}_{it} + \beta_2'Income_{it} + \beta_3'\mathrm{Trade}_{it} + \\ \quad +\beta_4'\mathrm{HC}_{it} + \beta_5'\mathrm{Urban}_{it} + \beta_6'\mathrm{Internet}_{it} + \beta_7'\mathrm{CRisk}_{it} + \gamma_i' + \delta_t' + \varepsilon_{it}' \end{cases} \quad (5)$$

Next, the study examines the influences of climate risk on three dimensions of each sub-sector including financial access, financial depth, and financial efficiency. As similar as the case of two sub-sectors, three dimensions of each sector would have linkages together, while two sub-sectors are related. As such, the study would simultaneously estimate impacts of coping incapacity to climate events on these dimensions in the system equation below:

As the case of financial institutions and financial markets, this study employs SUR model to estimate the system Eq. (6).

Results and discussions

Empirical findings

First, the Table 2 presents the influences of lack of coping capacities to climate risk on overall financial development in

$$\begin{cases} \mathrm{FID}_{it} = \beta_0^1 + \beta_{11}^1 Inst_{it} + \beta_{12}^1 Colony_{it} + \beta_{13}^1 Socialist_{it} + \beta_{14}^1 Civillaw_{it} + \\ \quad +\beta_{15}^1\mathrm{Religion}_{it} + \beta_{16}^1\mathrm{Lanague}_{it} + \beta_2^1\mathrm{Income}_{it} + \beta_3^1\mathrm{Trade}_{it} + \\ \quad +\beta_4^1\mathrm{HC}_{it} + \beta_5^1\mathrm{Urban}_{it} + \beta_6^1 Internet_{it} + \beta_7^1\mathrm{CRisk}_{it} + \gamma_i^1 + \delta_t^1 + \varepsilon_{it}^1 \\ \mathrm{FIA}_{it} = \beta_0^2 + \beta_{11}^2\mathrm{Inst}_{it} + \beta_{12}^2\mathrm{Colony}_{it} + \beta_{13}^2\mathrm{Socialist}_{it} + \beta_{14}^2\mathrm{Civillaw}_{it} + \\ \quad +\beta_{15}^2\mathrm{Religion}_{it} + \beta_{16}^2\mathrm{Lanague}_{it} + \beta_2^2\mathrm{Income}_{it} + \beta_3^2\mathrm{Trade}_{it} + \\ \quad +\beta_4^2 HC_{it} + \beta_5^2\mathrm{Urban}_{it} + \beta_6^2\mathrm{Internet}_{it} + \beta_7^2\mathrm{CRisk}_{it} + \gamma_i^2 + \delta_t^2 + \varepsilon_{it}^2 \\ \mathrm{FIE}_{it} = \beta_0^3 + \beta_{11}^3\mathrm{Inst}_{it} + \beta_{12}^3\mathrm{Colony}_{it} + \beta_{13}^3\mathrm{Socialist}_{it} + \beta_{14}^3\mathrm{Civillaw}_{it} + \\ \quad +\beta_{15}^3\mathrm{Religion}_{it} + \beta_{16}^3\mathrm{Lanague}_{it} + \beta_2^3\mathrm{Income}_{it} + \beta_3^3\mathrm{Trade}_{it} + \\ \quad +\beta_4^3\mathrm{HC}_{it} + \beta_5^3\mathrm{Urban}_{it} + \beta_6^3\mathrm{Internet}_{it} + \beta_7^3\mathrm{CRisk}_{it} + \gamma_i^3 + \delta_t^3 + \varepsilon_{it}^3 \\ \mathrm{FMD}_{it} = \beta_0^4 + \beta_{11}^4\mathrm{Inst}_{it} + \beta_{12}^4\mathrm{Colony}_{it} + \beta_{13}^4\mathrm{Socialist}_{it} + \beta_{14}^4\mathrm{Civillaw}_{it} + \\ \quad +\beta_{15}^4\mathrm{Religion}_{it} + \beta_{16}^4\mathrm{Lanague}_{it} + \beta_2^4\mathrm{Income}_{it} + \beta_3^4\mathrm{Trade}_{it} + \\ \quad +\beta_4^4\mathrm{HC}_{it} + \beta_5^4\mathrm{Urban}_{it} + \beta_6^4\mathrm{Internet}_{it} + \beta_7^4\mathrm{CRisk}_{it} + \gamma_i^4 + \delta_t^4 + \varepsilon_{it}^4 \\ \mathrm{FMA}_{it} = \beta_0^5 + \beta_{11}^5 Inst_{it} + \beta_{12}^5\mathrm{Colony}_{it} + \beta_{13}^5\mathrm{Socialist}_{it} + \beta_{14}^5\mathrm{Civillaw}_{it} + \\ \quad +\beta_{15}^5\mathrm{Religion}_{it} + \beta_{16}^5\mathrm{Lanague}_{it} + \beta_2^5\mathrm{Income}_{it} + \beta_3^5\mathrm{Trade}_{it} + \\ \quad +\beta_4^5 HC_{it} + \beta_5^5\mathrm{Urban}_{it} + \beta_6^5\mathrm{Internet}_{it} + \beta_7^5\mathrm{CRisk}_{it} + \gamma_i^5 + \delta_t^5 + \varepsilon_{it}^5 \\ \mathrm{FME}_{it} = \beta_0^6 + \beta_{11}^6\mathrm{Inst}_{it} + \beta_{12}^6\mathrm{Colony}_{it} + \beta_{13}^6\mathrm{Socialist}_{it} + \beta_{14}^6\mathrm{Civillaw}_{it} + \\ \quad +\beta_{15}^6\mathrm{Religion}_{it} + \beta_{16}^6\mathrm{Lanague}_{it} + \beta_2^6\mathrm{Income}_{it} + \beta_3^6\mathrm{Trade}_{it} + \\ \quad +\beta_4^6\mathrm{HC}_{it} + \beta_5^6\mathrm{Urban}_{it} + \beta_6^6\mathrm{Internet}_{it} + \beta_7^6\mathrm{CRisk}_{it} + \gamma_i^6 + \delta_t^6 + \varepsilon_{it}^6 \end{cases} \quad (6)$$

global sample across five quantiles of the outcome variables (0.1, 0.25, 0.75, and 0.90).[5]

In term of main explanatory variables, the results in Table 2 show that lack of coping capacities to climate risk appears to have significance negative effects in low quantiles (0.10, 0.25, 0.50) and insignificance negative effects in high quantiles of financial development (0.75, 0.90). This means that the increases in lack of coping capacities toward climate risk appear to be a harmful factor for overall financial development, especially in countries with low levels of financial development.

In term of control variables, the estimates show some main results. Overall, institutional quality (Inst) has a positive effect on overall financial development, which are statistical significance at high quantiles (0.50, 0.75, 0.90). Economic development (Income) has a positive relationship with overall financial development in quantiles 0.50. Moreover, Internet usage mostly has a positive but insignificant effect, and trade openness has a negative but insignificant impact. Both urbanization and human capital have positive effects and are statistical significance at quantiles 0.25 and 0.50.

Second, the simultaneous effects of climate risks on two sub-sectors (financial institutions and financial markets) for the global sample are estimated by SUR model and presented in Table 3.

In terms of main explanatory variables, as shown in Part A – Table 3, the lack of coping capacities has significantly negative impacts on both financial institutions (FI) and financial markets (FM) in global sample (model 1). The results are robust and consistent with subsample with high level of exposing to climate risk (model 3), while the effects are insignificant in subsample with low level of climate risk (model 2). It thus suggests that the negative effects of lack of coping capacities on financial institutions and financial markets are prominent only in countries with high exposing to climate risk, which is rational.

The results for three subsamples by income levels in Part B – Table 3 offer notable findings. The negative effects of lack of coping capacities on financial institutions and financial markets are statistically significant in high income countries (HICs—model 6). Meanwhile, the effects of lack of coping capabilities are only statistically significant in the effects on financial institutions (models 4–5). The findings imply that climate risk seem to be more important for financial institutions in low- and middle-income countries.

In term of control variables, formal institutional quality has significant positive effects, while informal institutions (Colony, Socialist, Civil law, Religion, and Language) have mixed coefficients. Country with colonial history, socialist history, one official language appears to have lower development of both sub-sectors since the estimated coefficients for these dummy variables are negative and significant at 1% level.

Meanwhile, country with civil law system seems to have higher financial institutions development but lower financial markets development. Economic development has positive effects on both sub-sectors, while internet usage, especially trade openness, appear to have negative effects. Human capital has a positive effect on financial institutions development but a negative one on financial markets development.

Third, the study estimates the simultaneous effects of climate risk on three dimensions of both sub-sectors. The results are presented in Table 4 above for the global sample. The results show that lack of coping capacities to climate risk mostly have significant negative impacts on all dimensions of two sub-sectors except the case of financial institutions efficiency. In our interpretation, it is possible that coping incapacity of a nation enhances financial efficiency of financial institutions. To the extent that financial efficiency for financial intermediaries refers to their profitability, it is possible that lack of capacity to cope with natural hazards in the national level offers financial institutions justifications to charge more to the financial service clients (and thus provide them with higher profitability). The simultaneously effects of climate risk on three dimensions of two sub-sectors are also estimated for three subsamples (LMCs, UMCs, and HICs) and reported in Tables A2, A3, A4 (Appendix), respectively. The summary is presented in Table 5 below.

In high-income countries (HICs), the results show that lack of coping capacities appears to have significant negative effects on all dimensions of two sub-sectors. In UMCs, lack of coping capacities has significant negative effects on financial access of both financial institutions and financial markets, while it has insignificant positive effects on other dimensions. In LICs, lack of coping capacities appears to only have a significant negative effect on financial institutions access, while effects on other dimensions are not statistical significance.

Discussions

The results of our study suggest that natural risk indicated by the lack of coping capacities to natural hazards have negative influences on overall financial development. Prior literature shows that some natural disasters may have a positive impact

[5] It is important to notice that variables of informal institutions (Colony, Socialist, Civil law, Religion, and Language) do not appear in the results in Table 2 since they are dummy variables that are omitted when regressing by panel quantile regressions.

Table 2 Climate risk and overall financial development: Panel quantile regression

Lack of coping capacities to climate risk and financial development					
Quantiles:	0.10	0.25	0.50	0.75	0.9
Dep. var: FD	(6)	(7)	(8)	(9)	(10)
Inst	0.0046	0.0103	0.0177**	0.0257***	0.0311**
	[0.0133]	[0.0096]	[0.0071]	[0.0094]	[0.0128]
Income	0.0248	0.0215*	0.0172*	0.0126	0.0094
	[0.0171]	[0.0125]	[0.0092]	[0.0122]	[0.0166]
Internet	0.0002	0.0002	0.0002*	0.0001	0.0001
	[0.0002]	[0.0001]	[0.0001]	[0.0001]	[0.0002]
Trade	−0.0001	−0.0001	−0.0001	−0.0001	−0.0001
	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0001]
HC	0.0350	0.0418	0.0508**	0.0603*	0.0668
	[0.0451]	[0.0328]	[0.0241]	[0.0321]	[0.0437]
Urban	0.0031**	0.0027**	0.0021***	0.0015	0.0011
	[0.0015]	[0.0011]	[0.0008]	[0.0011]	[0.0014]
LCop	−0.0019**	−0.0016***	−0.0012***	−0.0008	−0.0005
	[0.0008]	[0.0006]	[0.0004]	[0.0006]	[0.0008]
Observations	1170	1170	1170	1170	1170

Results are estimated by the panel quantile regression with fixed effects; standard errors are in brackets; *, **, *** are significance levels at 10%, 5%, and 1%, respectively

in the long run on energy consumption (Doytch and Klein 2018) and FDI (Doytch 2020). Such positive association can be explained by the *"creative destruction"* growth hypothesis when economies witness the increased energy and capital demand associated with rebuilding process and replacing outdated technologies. As argued previously, the negative effects of climate risk on financial development could originate from both demand and supply side. In other words, the risk and uncertainty of catastrophic events would lead to rational responses from both fund providers (e.g., banks) and users (e.g., firms). Specifically, risk and uncertainty associated with climate exposure create negative repercussions on economic activities, thereby decreasing risky activities such as credit provision (the supply side) and deteriorating investment activities (the demand side) of firms and households.

These findings also reveal that the heterogeneous influences of lack of coping capacity on natural hazards depend on the levels of financial development. Specifically, countries with lower levels of financial development would be hit harder by such incapacity, and vice versa for countries with higher levels of financial development. Such evidence is in accordance with Melecky and Raddatz (2015) and McDermott et al. (2014), suggesting that financial development may restrain disaster consequences via easing financial constraints of economic agents in the aftermath. We also share a common view with Klomp (2016) which shows a larger impacts of natural disasters on the economic outcome of countries with lower financial development. Indeed, in countries characterized by highly developed economic and financial markets, the exercise of risk management and diversification strategies is more feasible, thereby alleviating the negative dampen effects of natural risk. To a broader literature, since financial development matters for economic development (Levine and Zervos 1996; King and Levine 1993), this study offers a possible mechanism explaining the negative association between natural disasters and economic growth. McDermott et al. (2014) also find that the negative consequences of natural disasters is alleviated by higher financial development.

Moreover, our works highlight the notion that climate risks, measured by the lack of coping capacities, exert strong and negative repercussions on both financial institutions and financial markets. Thus, enhancing capabilities of societies to minimize negative impacts of natural hazards and climate change through direct actions and available resources should be on the agendas of policymakers.

By conducting deep analysis on six dimensions of the development of financial institutions and financial markets, the results comprehensively reveal the vulnerabilities of financial institutions' functions (depth and access) to climate risk. Specifically, access to financial services provided by financial institutions is negatively related to the lack of coping capabilities to climate risk. Our evidence is thus in line with a relevant study by Berg and Schrader (2012), who point to a reduction in credit access after a shock of natural disaster.

The effects of climate risk seem to have heterogeneous impacts on financial development across countries with different levels of economic development. The positive effects of exposure to climate risk are found in various specifications focusing on LMCs, which are in accordance with (Keerthiratne and Tol 2017).

Table 3 Climate risk and financial development: two sub-sectors

Part A: Full sample						
SUR estimates	(1)– Full sample		(2)– Countries with low exposing to natural hazards		(3)– Countries with high exposing to natural hazards	
Dep. var:	FI	FM	FI	FM	FI	FM
Inst	0.0737***	0.0118	0.0917***	0.0386**	0.0413***	0.0184
	[0.0100]	[0.0151]	[0.0135]	[0.0180]	[0.0128]	[0.0263]
Colony	−0.0189**	−0.0775***	−0.0089	−0.0479***	−0.0146	−0.1067***
	[0.0075]	[0.0114]	[0.0105]	[0.0140]	[0.0090]	[0.0184]
Socialist	−0.0331***	−0.1064***	−0.0127	−0.1161***	−0.0759***	−0.1060***
	[0.0072]	[0.0109]	[0.0097]	[0.0128]	[0.0083]	[0.0170]
Civil law	0.0086	−0.0609***	0.0281***	−0.0554***	0.0022	−0.0326*
	[0.0073]	[0.0111]	[0.0107]	[0.0142]	[0.0084]	[0.0173]
Religion	0.0183***	0.0027	0.0239**	−0.0111	0.0059	−0.0044
	[0.0069]	[0.0104]	[0.0099]	[0.0131]	[0.0071]	[0.0145]
Language	−0.0271***	−0.0478***	−0.0408***	−0.0590***	0.0277***	0.0229
	[0.0074]	[0.0112]	[0.0100]	[0.0133]	[0.0090]	[0.0184]
Income	0.0493***	0.1117***	0.0569***	0.1582***	0.0349***	0.0076
	[0.0070]	[0.0107]	[0.0096]	[0.0128]	[0.0085]	[0.0174]
Internet	−0.0005*	0.0000	−0.0006*	−0.0004	−0.0001	0.0000
	[0.0002]	[0.0004]	[0.0003]	[0.0004]	[0.0003]	[0.0006]
Trade	−0.0003***	−0.0008***	−0.0003***	−0.0011***	−0.0003***	−0.0002
	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0002]
HC	0.1032***	−0.1077***	0.1390***	−0.1263***	0.0616**	0.1147**
	[0.0190]	[0.0289]	[0.0252]	[0.0335]	[0.0248]	[0.0509]
Urban	−0.0001	−0.0002	0.0000	−0.0002	−0.0010***	−0.0017***
	[0.0002]	[0.0004]	[0.0003]	[0.0004]	[0.0003]	[0.0006]
LCop	−0.0031***	−0.0050***	−0.0008	−0.0012	−0.0073***	−0.0119***
	[0.0007]	[0.0011]	[0.0010]	[0.0014]	[0.0009]	[0.0018]
Constant	0.2100**	−0.0446	−0.0590	−0.6214***	0.6735***	1.1002***
	[0.0897]	[0.1361]	[0.1262]	[0.1679]	[0.1062]	[0.2178]
Observations	1,170	1,170	782	782	388	388
R-squared	0.7599	0.6667	0.7222	0.7006	0.8860	0.7099

Part B: Three subsamples by income levels						
SUR estimates	4 – LMEs		5 – UMEs		6 – HIEs	
Dep. var:	FI	FM	FI	FM	FI	FM
Inst	0.0246***	0.0504***	0.0933***	−0.0274	0.0646***	−0.1553***
	[0.0094]	[0.0126]	[0.0270]	[0.0434]	[0.0226]	[0.0331]

Table 3 (continued)

Colony	−0.0009	−0.0054	−0.0579***	−0.1249***	0.0453***	−0.1471***
	[0.0070]	[0.0094]	[0.0186]	[0.0299]	[0.0166]	[0.0243]
Socialist	−0.0350***	−0.0576***	0.0247	−0.0298	−0.1205***	−0.1931***
	[0.0066]	[0.0088]	[0.0230]	[0.0370]	[0.0195]	[0.0285]
Civil law	0.0176**	−0.0145	−0.0259	−0.0939***	0.0387**	−0.0653***
	[0.0073]	[0.0099]	[0.0175]	[0.0282]	[0.0164]	[0.0240]
Religion	0.0172**	0.0128	0.0486***	0.1385***	−0.0068	−0.0950***
	[0.0073]	[0.0098]	[0.0176]	[0.0282]	[0.0140]	[0.0205]
Language	−0.0149**	−0.0060	0.0028	0.0050	−0.0041	−0.0870***
	[0.0067]	[0.0090]	[0.0165]	[0.0265]	[0.0183]	[0.0267]
Income	0.0577***	0.0639***	0.0206	0.3120***	0.0294	0.1873***
	[0.0071]	[0.0095]	[0.0267]	[0.0429]	[0.0202]	[0.0296]
Internet	0.0008***	0.0008**	0.0012**	0.0011	−0.0014***	−0.0013*
	[0.0003]	[0.0003]	[0.0005]	[0.0008]	[0.0005]	[0.0007]
Trade	−0.0000	−0.0010***	0.0007**	0.0003	−0.0003***	−0.0006***
	[0.0001]	[0.0001]	[0.0003]	[0.0005]	[0.0001]	[0.0001]
HC	0.0095	0.0346	−0.2639***	−0.4195***	0.3174***	−0.0269
	[0.0177]	[0.0237]	[0.0746]	[0.1199]	[0.0550]	[0.0804]
Urban	−0.0000	−0.0008**	−0.0004	−0.0018*	−0.0013**	0.0006
	[0.0003]	[0.0004]	[0.0007]	[0.0011]	[0.0005]	[0.0008]
LCop	−0.0048***	−0.00001	−0.0048***	−0.0010	−0.0057***	−0.0099***
	[0.0010]	[0.0013]	[0.0020]	[0.0031]	[0.0014]	[0.0021]
Constant	0.2454***	−0.2572**	0.8224**	−1.9209***	0.4456*	−0.3197
	[0.0923]	[0.1239]	[0.3576]	[0.5750]	[0.2537]	[0.3712]
Observations	450	450	279	279	441	441
R-squared	0.5947	0.4212	0.3548	0.3534	0.5940	0.6293

Results are estimated by the seemingly unrelated regressions (SUR); in models (2) and (3): the mean of exposing to natural hazards (see Table 1 with value of 14.7) is used as the hurdle to divide the full sample into two subsamples: low and high exposing to natural hazards); the standard errors are in brackets; *, **, *** are significance levels at 10%, 5%, and 1%, respectively

Table 4 Climate risk and financial development: three dimensions in two sub-sectors

Dep. var:	FID	FIA	FIE	FMD	FMA	FME
Inst	0.2041***	−0.0509***	0.0391***	0.0434**	−0.0249	0.0108
	[0.0140]	[0.0155]	[0.0098]	[0.0174]	[0.0172]	[0.0243]
Colony	−0.0276***	−0.0014	−0.0266***	−0.0646***	0.0301**	−0.1994***
	[0.0106]	[0.0117]	[0.0074]	[0.0132]	[0.0130]	[0.0184]
Socialist	−0.0705***	−0.0216*	0.0218***	−0.1307***	−0.1107***	−0.0699***
	[0.0101]	[0.0111]	[0.0070]	[0.0125]	[0.0124]	[0.0175]
Civil law	−0.0553***	0.0958***	−0.0349***	−0.0667***	−0.0501***	−0.0632***
	[0.0103]	[0.0114]	[0.0072]	[0.0128]	[0.0127]	[0.0178]
Religion	0.0100	0.0400***	−0.0109	0.0005	0.0362***	−0.0284*
	[0.0097]	[0.0107]	[0.0067]	[0.0120]	[0.0119]	[0.0168]
Language	−0.0641***	0.0036	−0.0070	−0.0601***	−0.0492***	−0.0302*
	[0.0104]	[0.0115]	[0.0073]	[0.0130]	[0.0128]	[0.0181]
Income	0.0317***	0.0637***	0.0352***	0.0917***	0.1146***	0.1295***
	[0.0099]	[0.0109]	[0.0069]	[0.0123]	[0.0122]	[0.0172]
Internet	−0.0007*	−0.0007*	0.0005**	0.0001	0.0014***	−0.0015**
	[0.0003]	[0.0004]	[0.0002]	[0.0004]	[0.0004]	[0.0006]
Trade	−0.0005***	−0.0001	−0.0001	−0.0006***	0.0002	−0.0018***
	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0002]
HC	0.0463*	0.2091***	−0.0196	−0.1747***	−0.1125***	−0.0200
	[0.0268]	[0.0296]	[0.0187]	[0.0333]	[0.0329]	[0.0465]
Urban	0.0002	−0.0004	−0.0001	0.0001	−0.0013***	0.0008
	[0.0004]	[0.0004]	[0.0002]	[0.0004]	[0.0004]	[0.0006]
LCop	−0.0014	−0.0079***	0.0032***	−0.0061***	−0.0048***	−0.0038**
	[0.0011]	[0.0012]	[0.0007]	[0.0013]	[0.0013]	[0.0018]
Constant	0.2538**	0.1724	0.1199	0.2595*	−0.2305	−0.2180
	[0.1264]	[0.1394]	[0.0882]	[0.1570]	[0.1554]	[0.2191]
Observations	1,170	1,170	1,170	1,170	1,170	1,170
R-squared	0.7141	0.6370	0.1333	0.6279	0.6206	0.4445

Results are estimated by the seemingly unrelated regressions (SUR); standard errors are in brackets; *, **, *** are significance levels at 10%, 5%, and 1%, respectively

Table 5 Climate risk and financial development: three dimensions in two sub-sectors for three subsamples (summary)

LMCs sample, SUR estimate						
Dep. var:	FID	FIA	FIE	FMD	FMA	FME
LCop	–	–[a]	–	+	+	–
UMCs sample, SUR estimate						
Dep. var:	FID	FIA	FIE	FMD	FMA	FME
LCop	+	–[a]	+	+	–[a]	+
HICs sample, SUR estimate						
Dep. var:	FID	FIA	FIE	FMD	FMA	FME
LCop	–[a]	–[b]	–[c]	–[a]	–[a]	–[a]

Detail results are reported in Tables A2-A4 (Appendix); the results are the simultaneously effects of each indicator of climate risk (*LCop*) on six indicators of financial development by the Seemingly unrelated regressions (SUR); +/– are positive/negative coefficients of each indicator of climate risk on each financial development indicator; [a, b, c] are significance levels at 10%, 5%, and 1%, respectively

Conclusions

Using a sample of 130 countries from 2011 to 2019, we provide the first empirical investigation on the impacts of national vulnerability towards climate risk exposure (due to lack of coping capacity) on the development of financial institutions and financial markets. The overall results, based on panel quintile regressions, suggest that the lack of coping capacity significantly impedes financial development, especially in countries with low financial development levels. Nevertheless, the more complex dynamics of the relation are also worth noting when we further disaggregate countries into three different income groups to gain deeper understanding of the influences of climate risk. For example, the results indicate that the lack of coping capacities has significantly negative impacts on the development of both financial institutions and financial markets in HICs, while it is more importance for financial institutions in LICs and UMCs. Lastly, a closer look into different dimensions of financial development itself reveals that coping incapacity appears to have significant negative impacts on most dimensions of two sub-sectors (financial institutions and financial markets). Remarkably, the lack of coping capacity to natural hazards has positive effects on financial institutions efficiency (and thus allowing them to profit more in the process). The finer details of the relations offer insights to policy makers and warrant further looks into various aspects of this dynamic.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11356-023-26621-1.

Author contribution Canh Phuc Nguyen: conceptualization, methodology, software, data curation, formal analysis, writing- original draft preparation, writing—reviewing and editing; Duc Nguyen Nguyen: validation, writing—original draft preparation, writing—reviewing and editing; Jeff Wongchoti: writing—original draft preparation, writing—reviewing and editing.

Funding The study is funded by the University of Economics Ho Chi Minh City (UEH), Vietnam by the decision 3146/QĐ-ĐHKT-KTLQLNN dated 18 Oct 2022 and the number of project CELG-2022-03.

Data availability Data and materials are provided by corresponding author upon reasonable requests.

Declarations

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent to publish Not applicable.

Competing interests The authors declare no competing interests.

References

Acemoglu D, Johnson S, Robinson JA (2001) The colonial origins of comparative development: an empirical investigation. Am Econ Rev 91(5):1369–1401

Altunbaş Y, Thornton J (2019) The impact of financial development on income inequality: a quantile regression approach. Econ Lett 175:51–56. https://doi.org/10.1016/j.econlet.2018.12.030

Ang JB (2019) Culture, legal origins, and financial development. Econ Inq 57(2):1016–1037. https://doi.org/10.1111/ecin.12755

Anginer D, Bertay AC, Cull R, Demirguc-Kunt A, Mare DS (2019a) Bank regulation and supervision ten years after the global financial crisis. Retrieved from Washington, DC. https://openknowledge.worldbank.org/handle/10986/32589. Accessed 20 Dec 2022

Anginer D, Bertay AC, Cull R, Demirgüç-Kunt A, Mare DS (2019b) Bank regulation and supervision ten years after the global financial crisis. World Bank Policy Research Working Paper(9044), World Bank, Washington, D.C

Ashraf BN (2018) Do trade and financial openness matter for financial development? Bank-level evidence from emerging market economies. Res Int Bus Financ 44:434–458. https://doi.org/10.1016/j.ribaf.2017.07.115

Asyahid EA, Pekerti IS (2022) Economic impact of natural disasters, spillovers, and role of human development: case of Indonesia. Lett Spat Resour Sci. https://doi.org/10.1007/s12076-022-00307-7

Bai H, Ba S, Huang W, Hu W (2020) Expected government support and bank risk-taking: evidence from China. Financ Res Lett 36:101328. https://doi.org/10.1016/j.frl.2019.101328

Barrett CB, Barnett BJ, Carter MR, Chantarat S, Hansen JW, Mude AG, Osgood D, Skees JR, Turvey CG, Ward MN (2007) Poverty traps and climate risk: limitations and opportunities of index-based risk financing. IRI Technical Report No. 07-02, Available at SSRN: https://ssrn.com/abstract=1141933 or https://doi.org/10.2139/ssrn.1141933. Accessed 15 Jan 2023

Beck T, Demirgüç-Kunt A, Levine R (2003) Law, endowments, and finance. J Financ Econ 70(2):137–181. https://doi.org/10.1016/S0304-405X(03)00144-2

Beck T, Levine R, Loayza N (2000) Finance and the sources of growth. J Financ Econ 58(1):261–300. https://doi.org/10.1016/S0304-405X(00)00072-6

Bekaert G, Harvey CR, Lumsdaine RL (2002) Dating the integration of world equity markets. J Financ Econ 65(2):203–247. https://doi.org/10.1016/S0304-405X(02)00139-3

Berg G, Schrader J (2012) Access to credit, natural disasters, and relationship lending. J Financ Intermediation 21(4):549–568. https://doi.org/10.1016/j.jfi.2012.05.003

Bertocchi G, Canova F (2002) Did colonization matter for growth?: An empirical exploration into the historical causes of Africa's underdevelopment. Eur Econ Rev 46(10):1851–1871. https://doi.org/10.1016/S0014-2921(01)00195-7

Bertola G, Guiso L, Pistaferri L (2005) Uncertainty and consumer durables adjustment. Rev Econ Stud 72(4):973–1007

Birkmann J, Welle T (2015) Assessing the risk of loss and damage: exposure, vulnerability and risk to climate-related hazards for different country classifications. Int J Glob Warm 8(2):191–212. https://doi.org/10.1504/IJGW.2015.071963

Bittencourt M, Chang S, Gupta R, Miller SM (2019) Does financial development affect income inequality in the U.S. States? J Policy Model. https://doi.org/10.1016/j.jpolmod.2019.07.008

Bloom N (2009) The impact of uncertainty shocks. Econometrica 77(3):623–685

Bloom N, Bond S, Van Reenen J (2007) Uncertainty and investment dynamics. Rev Econ Stud 74(2):391–415

Bourdeau-Brien M, Kryzanowski L (2020) Natural disasters and risk aversion. J Econ Behav Organ 177:818–835. https://doi.org/10.1016/j.jebo.2020.07.007

Bowen A, Cochrane S, Fankhauser S (2012) Climate change, adaptation and economic growth. Clim Change 113(2):95–106. https://doi.org/10.1007/s10584-011-0346-8

Boyd JH, Levine R, Smith BD (2001) The impact of inflation on financial sector performance. J Monet Econ 47(2):221–248. https://doi.org/10.1016/S0304-3932(01)00049-6

Brei M, Mohan P, Strobl E (2019) The impact of natural disasters on the banking sector: evidence from hurricane strikes in the Caribbean. Q Rev Econ Finance 72:232–239. https://doi.org/10.1016/j.qref.2018.12.004

Busch T, Bauer R, Orlitzky M (2016) Sustainable development and financial markets:old paths and new avenues. Bus Soc 55(3):303–329. https://doi.org/10.1177/0007650315570701

Caggiano G, Castelnuovo E, Figueres JM (2017) Economic policy uncertainty and unemployment in the United States: a nonlinear approach. Econ Lett 151:31–34. https://doi.org/10.1016/j.econlet.2016.12.002

Caggiano G, Castelnuovo E, Groshenny N (2014) Uncertainty shocks and unemployment dynamics: an analysis of post-WWII US recessions. J Monet Econ 67:78–92

Canh NP, Thanh SD (2020) Financial development and the shadow economy: a multi-dimensional analysis. Econ Anal Policy 67:37–54. https://doi.org/10.1016/j.eap.2020.05.002

Cesa-Bianchi A, Pesaran MH, Rebucci A (2019) Uncertainty and economic activity: a multicountry perspective. Rev Financ Stud 33(8):3393–3445. https://doi.org/10.1093/rfs/hhz098

Challinor AJ, Adger WN, Benton TG (2017) Climate risks across borders and scales. Nat Clim Chang 7(9):621–623. https://doi.org/10.1038/nclimate3380

Chang CP, Berdiev AN (2013) Natural disasters, political risk and insurance market development. Geneva Pap Risk Insur Issues Pract 38(3):406–448. https://doi.org/10.1057/gpp.2013.14

Charpentier A (2008) Insurability of climate risks. Geneva Pap Risk Insur Issues Pract 33(1):91–109. https://doi.org/10.1057/palgrave.gpp.2510155

Chen LH, Silva Gao L (2012) The pricing of climate risk. J Financ Econ Pract Spring 12(2):115–131. https://doi.org/10.2139/ssrn.1940727

Cheng C-Y, Chien M-S, Lee C-C (2021) ICT diffusion, financial development, and economic growth: an international cross-country analysis. Econ Model 94:662–671. https://doi.org/10.1016/j.econmod.2020.02.008

Chinn MD, Ito H (2006) What matters for financial development? Capital controls, institutions, and interactions. J Dev Econ 81(1):163–192. https://doi.org/10.1016/j.jdeveco.2005.05.010

Chiu Y-B, Lee C-C (2019) Financial development, income inequality, and country risk. J Int Money Financ 93:1–18. https://doi.org/10.1016/j.jimonfin.2019.01.001

Choi S, Loungani P (2015) Uncertainty and unemployment: the effects of aggregate and sectoral channels. J Macroecon 46:344–358. https://doi.org/10.1016/j.jmacro.2015.10.007

Čihák M, Demirgüç-Kunt A, Feyen E, Levine R (2012) Benchmarking financial development around the world. World Bank Policy Res Work Pap 6175:1–54

Collier B, Skees J (2012) Increasing the resilience of financial intermediaries through portfolio-level insurance against natural disasters. Nat Hazards 64(1):55–72. https://doi.org/10.1007/s11069-012-0227-0

Colombo V (2013) Economic policy uncertainty in the US: does it matter for the Euro area? Econ Lett 121(1):39–42

Cortellini G, Panetta IC (2021) Green bond: a systematic literature review for future research agendas. J Risk Financ Manag 14(12):589. Retrieved from https://www.mdpi.com/1911-8074/14/12/589. Accessed 10 Dec 2022

Dell M, Jones BF, Olken BA (2008) Climate change and economic growth: evidence from the last half century. NEBR WORKING PAPER 14132, National Bureau of Economic Research, Cambridge. https://doi.org/10.3386/w14132

Dell M, Jones BF, Olken BA (2009) Temperature and income: reconciling new cross-sectional and panel estimates. Am Econ Rev 99(2):198–204. https://doi.org/10.1257/aer.99.2.198

Do Q-T, Levchenko AA (2004) Trade and financial development. Available at SSRN 610391. Retrieved from https://ssrn.com/abstract=610391. Accessed 13 Nov 2022

Do QA, Phan V, Nguyen DT (2022) How do local banks respond to natural disasters? Eur J Financ 1–26. https://doi.org/10.1080/1351847X.2022.2055969

Doytch N (2020) Upgrading destruction? Int J Clim Change Strategies Manag 12(2):182–200. https://doi.org/10.1108/IJCCSM-07-2019-0044

Doytch N, Klein YL (2018) The impact of natural disasters on energy consumption: an analysis of renewable and nonrenewable energy demand in the residential and industrial sectors. Environ Prog Sustain Energy 37(1):37–45. https://doi.org/10.1002/ep.12640

Easterly W, Levine R (2003) Tropics, germs, and crops: how endowments influence economic development. J Monet Econ 50(1):3–39. https://doi.org/10.1016/S0304-3932(02)00200-3

Eckstein D, Künzel V, Schäfer L (2021) Global climate risk index 2021. Who suffers most from extreme weather events, 2000–2019. Retrieved from https://www.developmentaid.org/api/frontend/cms/file/2021/03/Global-Climate-Risk-Index-2021_1.pdf.

Elijido-Ten EO, Clarkson P (2019) Going beyond climate change risk management: insights from the world's largest most sustainable corporations. J Bus Ethics 157(4):1067–1089. https://doi.org/10.1007/s10551-017-3611-6

Feenstra RC, Inklaar R, Timmer MP (2015) The next generation of the Penn World Table. Am Econ Rev 105(10):3150–3182. https://doi.org/10.1257/aer.20130954

Fuhrer J, Beniston M, Fischlin A, Frei C, Goyette S, Jasper K, Pfister C (2006) Climate risks and their impact on agriculture and forests in Switzerland. In: Wanner H, Grosjean M, Röthlisberger R, Xoplaki E (eds) Climate variability, predictability and climate risks: a European perspective. Springer, Netherlands, Dordrecht, pp 79–102

Gallup JL, Sachs JD, Mellinger AD (1999) Geography and economic development. Int Reg Sci Rev 22(2):179–232. https://doi.org/10.1177/016001799761012334

Gangi F, Meles A, D'Angelo E, Daniele LM (2019) Sustainable development and corporate governance in the financial system: are environmentally friendly banks less risky? Corp Soc Responsib Environ Manag 26(3):529–547. https://doi.org/10.1002/csr.1699

Ghimire KM (2021) Natural disasters and weak government institutions: creating a vicious cycle that ensnares developing countries. Law Dev Rev 14(1):59–104. https://doi.org/10.1515/ldr-2020-0014

Hafer RW (2016) Cross-country evidence on the link between IQ and financial development. Intelligence 55:7–13. https://doi.org/10.1016/j.intell.2015.12.008

Hao L, Naiman DQ (2007). Quantile Regression. https://doi.org/10.4135/9781412985550

Hilft BE (2020) WorldRiskReport 2020. Retrieved from Berlin, Germany. https://weltrisikobericht.de/english/. Accessed 10 Sept 2022

Hong H, Li FW, Xu J (2019) Climate risks and market efficiency. J Econom 208(1):265–281. https://doi.org/10.1016/j.jeconom.2018.09.015

Hosono K, Miyakawa D, Uchino T, Hazama M, Ono A, Uchida H, Uesugi I (2016) Natural disasters, damage to banks, and firm investment. Int Econ Rev 57(4):1335–1370. https://doi.org/10.1111/iere.12200

Huang J-T, Wu L (2018) Climate volatility and household saving in China. J Financ Couns Plan 29(1):132–141. https://doi.org/10.1891/1052-3073.29.1.132

Huang Y (2010) Determinants of financial development. Palgrave Macmillan, London. https://doi.org/10.1057/9780230302495
Huybens E, Smith BD (1999) Inflation, financial markets and long-run real activity. J Monet Econ 43(2):283–315. https://doi.org/10.1016/S0304-3932(98)00060-9
IPCC (2021) Climate change widespread, rapid, and intensifying. Intergovernmental Panel on Climate Change (IPCC). Retrieved from https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/. Accessed 20 Nov 2022
Jaffee D, Levonian M (2001) The structure of banking systems in developed and transition economies. Eur Financ Manag 7(2):161–181. https://doi.org/10.1111/1468-036X.00151
Jeucken M (2010) Sustainable finance and banking: The financial sector and the future of the planet. Routledge, Oxfordshire
Kapucu N, Liou KT (2014) Disasters and development: investigating an integrated framework. In: Kapucu N, Liou KT (eds) Disaster and development: examining global issues and cases. Springer International Publishing, Cham, pp 1–15
Karwowski E, Stockhammer E (2017) Financialisation in emerging economies: a systematic overview and comparison with Anglo-Saxon economies. Econ Politic Stud 5(1):60–86. https://doi.org/10.1080/20954816.2016.1274520
Keerthiratne S, Tol RSJ (2017) Impact of natural disasters on financial development. Econ Dis Clim Change 1(1):33–54. https://doi.org/10.1007/s41885-017-0002-5
Khan MA, Khan MA, Abdulahi ME, Liaqat I, Shah SSH (2019) Institutional quality and financial development: the United States perspective. J Multinatl Financ Manag 49:67–80. https://doi.org/10.1016/j.mulfin.2019.01.001
Kim D-H, Lin S-C, Suen Y-B (2010) Dynamic effects of trade openness on financial development. Econ Model 27(1):254–261. https://doi.org/10.1016/j.econmod.2009.09.005
King RG, Levine R (1993) Finance and growth: Schumpeter might be right*. Q J Econ 108(3):717–737. https://doi.org/10.2307/2118406
Klomp J (2014) Financial fragility and natural disasters: an empirical analysis. J Financ Stab 13:180–192. https://doi.org/10.1016/j.jfs.2014.06.001
Klomp J (2016) Economic development and natural disasters: a satellite data analysis. Glob Environ Chang 36:67–88. https://doi.org/10.1016/j.gloenvcha.2015.11.001
Koenker R, Bassett G (1978) Regression quantiles. Econometrica 46(1):33–50. https://doi.org/10.2307/1913643
Kron W (2000) Natural disasters: lessons from the past – concerns for the future. Geneva Pap Risk Insur Issues Pract 25(4):570–581. https://doi.org/10.1111/1468-0440.00083
Krueger P, Sautner Z, Starks LT (2020) The importance of climate risks for institutional investors. Rev Financ Stud 33(3):1067–1111. https://doi.org/10.1093/rfs/hhz137
La Porta R, Lopez-de-Silanes F, Shleifer A, Vishny R (1999) The quality of government. J Law Econ Org 15(1):222–279. https://doi.org/10.1093/jleo/15.1.222
La Porta R, Lopez-de-Silanes F, Shleifer A, Vishny RW (1997) Legal determinants of external finance. J Financ LII (3):1131–1150
Law SH, Azman-Saini WNW (2012) Institutional quality, governance, and financial development. Econ Governance 13(3):217–236. https://doi.org/10.1007/s10101-012-0112-z
Law SH, Habibullah MS (2009) The determinants of financial development: institutions, openness and financial liberalisation. South Afr J Econ 77(1):45–58. https://doi.org/10.1111/j.1813-6982.2009.01201.x
Lawson T (1985) Uncertainty and economic analysis. Econ J 95(380):909–927
Le T-H, Nguyen CP, Park D (2020) Financing renewable energy development: insights from 55 countries. Energy Res Soc Sci 68:101537
Levine R (1999) Financial development and economic growth: views and agenda. J Econ Lit 35(2):688–726. Retrieved from https://www.jstor.org/stable/2729790. Accessed 20 Aug 2022
Levine R, Loayza N, Beck T (2000) Financial intermediation and growth: causality and causes. J Monet Econ 46(1):31–77. https://doi.org/10.1016/S0304-3932(00)00017-9
Levine R, Zervos S (1996) Stock market development and long-run growth. World Bank Econ Rev 10(2):323–339. https://doi.org/10.1093/wber/10.2.323
Li H-M, Wang X-C, Zhao X-F, Qi Y (2021) Understanding systemic risk induced by climate change. Adv Clim Chang Res 12(3):384–394. https://doi.org/10.1016/j.accre.2021.05.006
Malik A, Temple JRW (2009) The geography of output volatility. J Dev Econ 90(2):163–178. https://doi.org/10.1016/j.jdeveco.2008.10.003
Mato, P, Costa A, da Silva C (2021) On the risk-based contagion of G7 banking system and the COVID-19 pandemic. Glob Bus Rev 0(0):09721509211026813. https://doi.org/10.1177/09721509211026813
McDermott TKJ, Barry F, Tol RSJ (2014) Disasters and development: natural disasters, credit constraints, and economic growth. Oxf Econ Pap 66(3):750–773. https://doi.org/10.1093/oep/gpt034
Melecky M, Raddatz C (2015) Fiscal responses after catastrophes and the enabling role of financial development. World Bank Econ Rev 29(1):129–149. https://doi.org/10.1093/wber/lht041
Mendelsohn R (2009) Climate change and economic growth. World Bank working paper 57759. World Bank, Washington, DC
Millner A (2013) On welfare frameworks and catastrophic climate risks. J Environ Econ Manag 65(2):310–325. https://doi.org/10.1016/j.jeem.2012.09.006
Mlachila M, Ouedraogo R (2019) Financial development curse in resource-rich countries: the role of commodity price shocks. Q Rev Econ Finance. https://doi.org/10.1016/j.qref.2019.04.011
Moudud-Ul-Huq S, Ashraf BN, Gupta AD, Zheng C (2018) Does bank diversification heterogeneously affect performance and risk-taking in ASEAN emerging economies? Res Int Bus Financ 46:342–362. https://doi.org/10.1016/j.ribaf.2018.04.007
Mumtaz H, Surico P (2018) Policy uncertainty and aggregate fluctuations. J Appl Economet 33(3):319–331
Nasir MA, Canh NP, Le TNL (2021) Environmental degradation & role of financialisation, economic development, industrialisation and trade liberalisation. J Environ Manage 277:111471
Nguyen CP (2022a) The "karma" of impact on the Earth: will humans take responsibility? Evidence of energy consumption and CO_2 emissions. Environ Sci Pollut Res 29(33):50686–50703. https://doi.org/10.1007/s11356-022-19461-y
Nguyen CP (2022b) Last chance to travel or safety first? The influence of exposure to natural hazards and coping capacities on tourism consumption. Tour Econ 0(0):13548166221077648. https://doi.org/10.1177/13548166221077648
Nguyen CP, Lee GS (2021) Uncertainty, financial development, and FDI inflows: global evidence. Econ Model 99:105473. https://doi.org/10.1016/j.econmod.2021.02.014
Nguyen CP, Su TD (2021a) Easing economic vulnerability: multidimensional evidence of financial development. Q Rev Econ Finance 81:237–252. https://doi.org/10.1016/j.qref.2021.06.007
Nguyen CP, Su TD (2021b) Financing the economy: the multidimensional influences of financial development on economic complexity. J Int Dev 33(4):644–684. https://doi.org/10.1002/jid.3541
Nguyen CP, Su TD (2021c) When 'uncertainty' becomes 'unknown': influences of economic uncertainty on the shadow economy. Ann Public Coop Econ n/a(n/a). https://doi.org/10.1111/apce.12336
Nguyen CP, Su TD, Bui TD, Dang VTB, Nguyen BQ (2021) Financial development and energy poverty: global evidence. Environ Sci Pollut Res 28(26):35188–35225. https://doi.org/10.1007/s11356-021-13038-x

Noy I (2009) The macroeconomic consequences of disasters. J Dev Econ 88(2):221–231. https://doi.org/10.1016/j.jdeveco.2008.02.005

Panwar V, Sen S (2019) Economic impact of natural disasters: an empirical re-examination. Margin: J Appl Econ Res 13(1):109–139. https://doi.org/10.1177/0973801018800087

Peeters H (2005) Sustainable development and the role of the financial world. In: Hens L, Nath B (eds) The World Summit on Sustainable Development: The Johannesburg Conference. Springer, Netherlands, Dordrecht, pp 241–274

Phillips CA, Caldas A, Cleetus R, Dahl KA, Declet-Barreto J, Licker R, Merner LD, Ortiz-Partida JP, Phelan AL, Spanger-Siegfried E, Talati S, Trisos CH, Carlson CJ (2020) Compound climate risks in the COVID-19 pandemic. Nat Clim Chang 10(7):586–588. https://doi.org/10.1038/s41558-020-0804-2

PhucCanh N, Trung Thong N (2020) Nexus between financialisation and natural resources rents: empirical evidence in a global sample. Resour Policy 66:101590. https://doi.org/10.1016/j.resourpol.2020.101590

Phuc Nguyen C, Dinh Su T, Doytch N (2020) The drivers of financial development: global evidence from internet and mobile usage. Inf Econ Policy 53:100892. https://doi.org/10.1016/j.infoecopol.2020.100892

Powell D (2022) Quantile regression with nonadditive fixed effects. Empir Econ. https://doi.org/10.1007/s00181-022-02216-6

Reynolds T, Flores A (1989) Foreign law: current sources of basic legislation in jurisdictions of the world. W.S. Hein, Buffalo

Rudebusch GD (2021) Climate change is a source of financial risk. FRBSF Economic Letter 2021(03):01–06

Sahay R, Čihák M, N'diaye P, Barajas A, Bi R, Ayala D, Gao Y, Kyobe A, Nguyen L, Saborowski C (2015) Rethinking financial deepening: stability and growth in emerging markets. In IMF staff discussion note. Washington, D.C., U.S: International Monetary Fund

Scanlan MK (2021) Climate risk is investment risk. J Envtl l Litig 36:1

Schaal E (2017) Uncertainty and unemployment. Econometrica 85(6):1675–1721. https://doi.org/10.3982/ECTA10557

Sorg L, Medina N, Feldmeyer D, Sanchez A, Vojinovic Z, Birkmann J, Marchese A (2018) Capturing the multifaceted phenomena of socioeconomic vulnerability. Nat Hazards 92(1):257–282. https://doi.org/10.1007/s11069-018-3207-1

Stock JH, Watson MW (2008) Heteroskedasticity-robust standard errors for fixed effects panel data regression. Econometrica 76(1):155–174. https://doi.org/10.1111/j.0012-9682.2008.00821.x

Stulz RM, Williamson R (2003) Culture, openness, and finance. J Financ Econ 70(3):313–349. https://doi.org/10.1016/S0304-405X(03)00173-9

Svirydzenka K (2016) Introducing a new broad-based index of financial development. IMF Working Paper No. 2016/005. International Monetary Fund, Washington, D.C

Urban MC (2015) Accelerating extinction risk from climate change. Science 348(6234):571–573. https://doi.org/10.1126/science.aaa4984

Usman M, Makhdum MSA, Kousar R (2021) Does financial inclusion, renewable and non-renewable energy utilization accelerate ecological footprints and economic growth? Fresh evidence from 15 highest emitting countries. Sustain Cities Soc 65:102590. https://doi.org/10.1016/j.scs.2020.102590

Voghouei H, Azali M, Jamali MA (2011) A survey of the determinants of financial development. Asian-Pacific Econ Lit 25(2):1–20. https://doi.org/10.1111/j.1467-8411.2011.01304.x

Wagner G (2022) Climate risk is financial risk. Science 376(6598):1139–1139. https://doi.org/10.1126/science.add2160

Worthington A, Valadkhani A (2004) Measuring the impact of natural disasters on capital markets: an empirical application using intervention analysis. Appl Econ 36(19):2177–2186. https://doi.org/10.1080/0003684042000282489

Wu J, Chen M, Jeon BN, Wang R (2017) Does foreign bank penetration affect the risk of domestic banks? Evidence from emerging economies. J Financ Stab 31:45–61. https://doi.org/10.1016/j.jfs.2017.06.004

Wu X, Guo J (2021) Natural disasters and economic growth——an empirical study using provincial panel data of China. Springer Books, in: Economic Impacts and Emergency Management of Disasters in China, edition 1, chapter 0. Springer, New York, pp 81–104

Yao X, Yasmeen R, Hussain J, Hassan Shah WU (2021) The repercussions of financial development and corruption on energy efficiency and ecological footprint: evidence from BRICS and next 11 countries. Energy 223:120063. https://doi.org/10.1016/j.energy.2021.120063

Zellner A (1962) An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. J Am Stat Assoc 57(298):348–368. https://doi.org/10.1080/01621459.1962.10480664

Zhang C, Zhu Y, Lu Z (2015) Trade openness, financial openness, and financial development in China. J Int Money Financ 59:287–309. https://doi.org/10.1016/j.jimonfin.2015.07.010

Zhang D, Managi S (2020) Financial development, natural disasters, and economics of the Pacific small island states. Econ Anal Policy 66:168–181. https://doi.org/10.1016/j.eap.2020.04.003

Zscheischler J, Westra S, van den Hurk BJJM, Seneviratne SI, Ward PJ, Pitman A, AghaKouchak A, Bresch DN, Leonard M, Wahl T, Zhang X (2018) Future climate risk from compound events. Nat Clim Chang 8(6):469–477. https://doi.org/10.1038/s41558-018-0156-3