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Implications of Major Adverse Events on Productivity

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Abstract

Since 2000, there have been three major global slowdowns, with the latest and most pronounced episode triggered by the COVID-19 pandemic. At the same time, many countries have faced major adverse events including natural disasters, wars, and financial crises, all of which can lead to long-lasting harm to productivity. Wars inflict particularly severe damage to productivity, while financial crises also lead to substantial losses, especially accompanied by a rapid build-up of debt. The greater frequency of natural disasters, especially climate disasters, means that they have the largest aggregate impact on productivity, as natural disasters have occurred most often and their frequency has doubled since 2000. Global adverse events can have large sustained negative effects on productivity through dislocating labor, tightening of credit, disrupting value chains, and decreasing innovation. Policies to counter the negative consequences of adverse shocks include accommodative fiscal policies, such as reconstruction spending on resilient infrastructure; transparent governance; efficient use of relief funds; as well as growth-friendly structural reforms. Appropriate policies and regulations concerning finance, construction, and environmental protection can help reduce the frequency of adverse shocks.

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Implications of Major Adverse Events on Productivity*

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1 Introduction

The aftermath of the 2007-09 global financial crisis (GFC) witnessed a broad-based slowdown in labor productivity growth lasting over a decade. This follows a typical pattern associated with adverse events such as natural disasters, wars and financial crises. These events often result in protracted economic losses through declines in both the level and growth rate of output, as well as persistent losses in labor productivity, measured as output per worker.[1] Among natural disasters, the COVID-19 pandemic—a major epidemiological disaster—is an adverse event on a massive global scale, and could have a large and persistent impact on global productivity.

The damage from adverse events comes through a variety of channels. Natural disasters and wars may damage key infrastructure and disrupt value chains (Acevedo et al., 2018; Cerra and Saxena, 2008). Financial crises increase uncertainty, damage confidence, impede access to finance, and lower corporate earnings—all developments that are likely to reduce investment. More generally, adverse events can dampen labor productivity by causing a loss of skills, and reducing the efficiency of job matching, as well as by disrupting knowledge creation, transfer, and acquisition. The growth of labor productivity is therefore likely to be impeded by declines in both the growth of total factor productivity (TFP) and capital deepening.[2]

Severe global biological disasters such as COVID-19 can damage labor productivity by affecting both supply and demand. Adverse supply-side effects can occur through the depletion of labor force; the tightening of financial conditions; and the disruption of supply chains, which are an important measure for the diffusion of innovation. The COVID-19 pandemic is also weighing sharply on aggregate demand, by depressing consumer demand for goods and services, eroding business confidence and investment, and raising financial costs (Baker et al., 2020; Ludvigson et al., 2020; Ma et al., 2020). Weaker aggregate demand can reduce the incentive for product innovation, quality improvement, slow technological progress and lower productivity. Furthermore, these negative impacts can be amplified by other factors such as cross-border spillovers, lingering financial vulnerabilities and the compounding effects of recessions. An analysis of economic developments around previous, smaller-scale epidemiological disasters can provide a framework for understanding the channels through which productivity could be affected by COVID-19, and the potential persistence of its effects (Dieppe, 2020).

The productivity losses that result from adverse events in emerging markets and developing economies (EMDEs) can reduce the rate of convergence to the advanced economy technology frontier. However, the effects of adverse events on labor productivity and output hinge not only on their magnitude, duration, and frequency, but also on country characteristics and circumstances, including the policy response and the pre-shock buffers established by policy makers. Large-scale

[1] See Blanchard et al. (2015); Cerra and Saxena (2017); Furceri and Mourougane (2012b); Hall (2014); Jordà et al. (2013); Kilic Celik et al. (2019); Ray and Esteban (2017).

[2] TFP growth captures growth in production not explained by increases in factor inputs (essentially capital and labor). Under a standard growth accounting decomposition, which relies on a number of special assumptions, TFP growth may be computed as a residual of labor productivity growth after deduction of the estimated contribution of the growth of capital per unit of labor (capital deepening). Labor productivity growth is prone to measurement issues, especially in countries where services, government or informal sectors account for large shares of the economy, but estimates of TFP growth depend additionally on a number of special assumptions, including that factors of production (labor and capital) are paid their marginal products, presumably under conditions of perfect competition and constant returns to scale (See Annex B).

and severe disasters are typically more damaging to labor productivity and output. Low-income countries (LICs) and countries that are already affected by fragile and conflict-affected situations (FCS) have generally been less able than other countries to cope with wars and climate disasters such as droughts. If sufficiently severe, natural disaster can trigger financial crises—particularly in countries with high levels of debt—or lead to conflicts and wars. Policies should be geared toward both reducing the likelihood of adverse shocks and alleviating their impacts. Depending on available policy space, countercyclical macroeconomic policies can help counter negative effects on investment, and labor markets. Successful examples include the fiscal and monetary stimulus undertaken after the GFC, and the COVID-19 pandemic in 2020 by many advanced economies and EMDEs and the international assistance provided for reconstruction in the aftermath of recent natural disasters in some FCS countries.[3] Structural policy frameworks—such as the quality of governance and business climates—can facilitate faster adjustment, protect vulnerable groups, and mitigate long-lasting damage to productivity.

This paper examines a wide range of adverse events to assess the extent to which they have had protracted effects on labor productivity and TFP. This study aims to shed light on the following questions:

- How frequently and through what channels have adverse events affected productivity?
- How have adverse events differed in the scale of their impact on productivity?
- What policies can help to mitigate the impact of adverse events on productivity?

This paper makes several contributions to an expanding literature on the impact on productivity of adverse events.

Systematic cross-country evaluation of adverse events on productivity. This paper is the first to undertake a systematic study of the effects of a broad range of adverse events—natural disasters, wars, and financial crises—on alternative productivity measures across a wide range of advanced economies, EMDEs, and LICs.

Comprehensive explorations of persistent effects on productivity. One key aspect of the effects of adverse events on productivity is their persistence. Several studies have documented protracted losses in output or productivity following business cycle downturns, recessions or financial crises.[4] This paper builds on and broadens previous work (Easterly et al., 1993; Mourougane, 2017), by assessing the channels, the magnitude of the losses, and the speed of recovery across a wide range of different types of adverse events.

Comprehensive discussion of supportive policy framework. This study analyzes feasible policies to mitigate the corrosive effects of negative shocks. It discusses the role of structural policies and reforms that can support productivity following adverse shocks. It also highlights the importance of fiscal space in building a cushion that can be used to counter productivity loss in a country hit by adverse events.

[3]The effectiveness of such assistance depends on the government's ability to efficiently spend the relief money where it is needed. Designing and deploying a disaster-response infrastructure with well-defined rules and procedures before disasters hit improves resilience and boosts the effectiveness of reconstruction efforts (Hallegatte and Rentschler, 2018).

[4]See Blanchard et al. (2015); Cerra and Saxena (2008); Hall (2014).

Main findings. The estimated results, broadly consistent with the literature, include the following:

- **Natural disasters have occurred more often than wars or financial crises and their frequency has increased since 2000.** Natural disasters can be subdivided into several distinct types: climate disasters such as floods and cyclones, biological disasters such as epidemics or insect infestations, and geophysical disasters such as earthquakes and volcanoes. In the period 1960-2018, the number of episodes of natural disasters was 25 times that of wars and 12 times that of financial crises. Climate-related events were the most frequent type of natural disaster, with a doubling of their frequency after 2000. LICs, and particularly Sub-Saharan Africa (SSA), were most affected by natural disasters. Biological and geophysical episodes are less frequent and are often more geographically contained.[5]

- **Severe disasters have lasting effects on productivity.** While wars inflict particularly severe and long-lasting damage to both capital and total factor productivity, the high frequency of climate disasters increases their importance as a source of damage to productivity. On average during 1960-2018, climate disasters reduced annual contemporaneous labor productivity by about 0.5 percent—about one-fifth of the impact of a typical war episode. However, climate disasters have occurred 25 times as frequently as wars, meaning their cumulative negative effects on productivity are larger. Moreover, while the frequency of severe natural disasters has stabilized since 2000, they have strong negative effects on productivity. After three years, severe climate disasters lower labor productivity by about 7 percent, mainly through weakened total factor productivity. Severe disasters can also trigger other types of adverse events such as financial crises and wars, thus compounding the corrosive effects on productivity.

- **Productivity is highly vulnerable to financial stress, especially when accompanied by a rapid build-up of debt.** Financial crises weigh heavily on productivity growth through a wide range of channels. During debt accumulation episodes associated with financial crises, cumulative productivity gains three years into the episode were 2 percentage points lower than in episodes without crises in EMDEs. The rapid build-up of debt in EMDEs since the GFC increases vulnerabilities to financial crises and limits the ability of countries to cope with other types of adverse events. The current COVID-19 is likely to exacerbate those vulnerabilities by further stretching public and private balance sheets.

- **Appropriate policies can help to prevent and to mitigate the effects of adverse events.** A rapid policy response to adverse events, including countercyclical macroeconomic policies and reconstruction spending when appropriate, can help to mitigate the negative effects on productivity. Improving institutions and the business climate can also help increase the pace of recovery following an adverse event. Appropriate policies and regulations with respect to finance, construction, and environmental protection can help reduce the frequency of adverse events. Fiscal space allows economies to fund recovery efforts after natural disasters, and sound fiscal policies tend to limit the likelihood of a financial crisis. Fiscal stimulus also helps cushion the severity of large adverse events such as severe biological disasters.

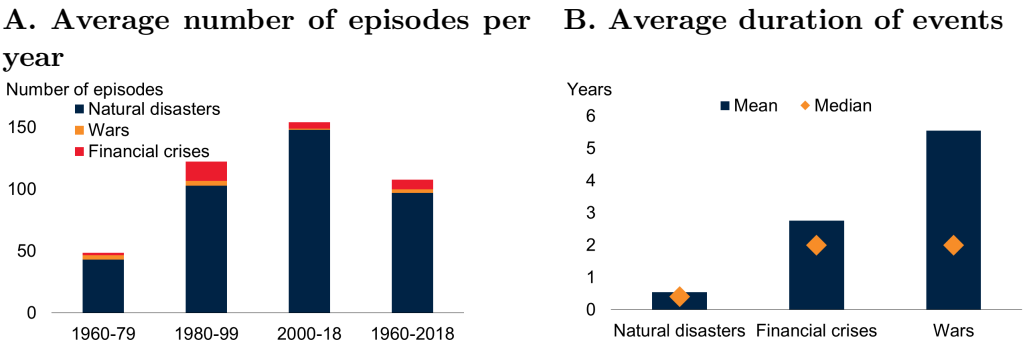
[5]The coronavirus epidemic is one of the very rare pandemics which has affected almost every country and region. This might be a signal of future pandemics with increasing international mobility of people (Jordà et al., 2020).

The remainder of this paper is organized as follows. Section 2 reviews the literature and seeks to identify the stylized facts relating to the effects of adverse events and the channels through which natural disasters, wars, and financial crises have affected productivity. Section 3 presents the data and the local projection estimation approach used to assess the empirical impacts of the adverse events on productivity. Section 4 describes the results of new research into the negative impacts of these adverse events on productivity across different groups of countries. Section 5 discusses the policy options available to counter the corrosive effects of adverse events on productivity. Section 6 concludes with a summary of the findings. Dieppe (2020) also focuses on the effects of epidemics on productivity.

2 Adverse events: Literature and stylized facts

This section reviews the literature on the economic effects of adverse events and documents their main features. It focuses on three main types of adverse events: natural disasters (climate, biological, and geophysical), wars (intra-state and external) and financial crises (banking, debt, and currency). The definitions of the events are provided in **Annex A**. Globally in the period 1960-2018, countries were far more frequently hit by natural disasters than by financial crises or wars (**Figure 1**).[6]

Figure 1: **Global frequency and duration of major adverse events, 1960-2018**



Correlates of War (COW); EM-DAT; Laeven and Valencia (2018); Peace Research Institute Oslo (PRIO); World Bank.
Note: Natural disasters include climate, biological, and geophysical disasters (EM-DAT). Wars include intra-state and external (extra-state and inter-state) wars (COW and PRIO). Financial crises include banking crisis, currency crisis, and sovereign debt crisis (Leaven and Valencia 2018). Definitions are in Annex A. An episode dummy for a specific type of event is 1 if the event occurs at least once ($\geq$1) in a country-year pair and 0 otherwise. The sample includes 170 economies: 35 advanced economies and 135 EMDEs, of which 27 are low-income countries.

While a specific type of event can occur many times in a country each year, an episode is defined if the event occurs at least once in a country in a year. Therefore, there are typically more occurrences than episodes. The remainder of this paper focuses on the impacts of episodes of natural disasters, wars and financial crises. The three broad types of adverse events are now explored in more detail.

[6]However, the frequency of severe natural disasters—defined as causing losses of life exceeding 100 people per million—stabilized after 2000, perhaps reflecting better mitigation policies in some countries as they have confronted climate change (**Figure 5**).

2.1 Natural disasters

Three types of natural disasters are considered: climate events (such as storms, floods, droughts, and periods of extreme temperature), biological events (such as epidemics and insect infestations), and geophysical events (such as earthquakes and volcanoes). Natural disasters, unlike financial crises, are typically measured in terms of the number of deaths and casualties, the number of people otherwise affected, and property damage.[7]

2.1.1 Transmission channels of natural disaster shock to productivity

Natural disasters can affect productivity through various channels:

- **Erosion of human capital.** The human cost of natural disasters can be substantial. They often lead to many fatalities and large population displacements. They also tend to degrade hygiene conditions in affected areas, increase the risk of large-scale outbreaks of infectious diseases and epidemics, and aggravate health challenges. In the case of a global pandemic such as COVID-19, the disruption of labor supply is exacerbated by containment measures that make it difficult for workers to get to their places of employment or work in close physical proximity with each other. Moreover, prolonged natural disasters can disrupt schooling, undermine learning conditions, and erode human capital through degraded work environments, sickness, etc. (Acevedo et al., 2018).

- **Destruction and misallocation of physical capital.** Natural disasters can destroy critical physical assets, damage major infrastructures, cut supply lines, and discourage private investment (Kunreuther, 2006). For the period 2000-12, the annual cost of natural disasters worldwide has been estimated to have been in excess of $100 billion (Kousky, 2014).[8] Moreover, major pandemics such as the COVID-19 hinder capital accumulation due to a substantial increase in uncertainty (World Bank, 2020). Natural disasters tend to reduce and degrade the capital stock, and can lead to a misallocation of the residual capital, since undamaged roads or offices (residual capital) often cannot be readily used in the way they had been, or used to replace or repair other damaged assets such as bridges or factories. This misallocation of capital weighs on labor productivity (Hallegatte and Vogt-Schilb, 2019).

- **Disruption of innovation.** Beyond the immediate loss of lives and damage to physical assets, natural disasters can lead to delayed or canceled investments in new technologies. The disruption of global value chains can also impede the creation, transfer, and adoption of new technologies (Asian Development Bank, 2019; Bloom et al., 2010). This was exemplified by the containment measures of the COVID-19 that have limited mobility, compressed trade and to some extent restricted the diffusion of innovation. Conversely, effective reconstruction efforts can boost investment and enhance productivity via upgraded capital, health improvements

[7] The number of people affected (excluding those killed) is usually considered to be the sum of people injured, made homeless, and otherwise requiring immediate assistance. Property damage includes damage to crops and livestock as well as real estate (**Annex A**).

[8] In assessing the economic cost of a disaster, it is important to avoid double-counting losses: the value of the damaged machine and the subsequent lost production should not both be counted as a loss.

and widespread use of new technologies.[9]

In addition to supply effects, due to the many unknowns, epidemics and pandemics can weigh on productivity through demand-side channels, by raising uncertainty, eroding consumer and business confidence, weakening investment and depressing demand (Dieppe, 2020).

Table 1: Number of episodes by type of events

	AEs	EMDEs	LICs	World
Natural disasters	**1031**	**4699**	**1098**	**5730**
Climate disaster	843	3054	651	3897
Biological disaster	50	953	369	1003
Geophysical disaster	138	692	78	830
Wars	**45**	**191**	**55**	**236**
Intra-state war	45	191	55	236
External war	45	68	9	113
Financial crises	**54**	**390**	**83**	**444**
Banking crisis	34	113	27	147
Currency crisis	18	208	44	226
Sovereign debt crisis	2	69	12	71

Note: Natural disasters include climate, biological, and geophysical disasters (EM-DAT). Wars include intra-state and external (extra-state and inter-state) wars (COW and PRIO). Financial crises include banking crisis, currency crisis, and sovereign debt crisis (Leaven and Valencia 2018). Sample is restricted to the observations where labor productivity growth data exist for the period 1960-2018. For each country-year pair, the episode dummy of a specific type of event is 1 if the event occurs at least once ($\geq$1), 0 otherwise. The total number of episodes (in bold) for each group of events (all financials, all disasters, all wars) may include events that occur simultaneously. The events are defined in **Annex A**. AEs = advanced economies, EMDEs = emerging markets and developing economies (including low income countries), LICs = low income countries.

2.1.2 Stylized facts for natural disasters

Increase in frequency of climate and other natural disasters. Climate disasters accounted for around 70 percent of natural disasters during 1960-2018, occurring twice as often as biological and geophysical disasters combined (**Figure 2**). From 1960-79 to 2000-18, there was a large increase in the number of natural disaster episodes.[10] Increases occurred in all three categories, but most

[9]The overall impact of a natural disaster depends partly on initial economic conditions. A disaster may be more economically damaging in periods of high employment and capacity utilization because the increase in output needed for reconstruction may not be feasible, and the increase in demand generated may induce inflation. By contrast, a disaster that occurs when the economy is depressed may cause less economic damage as the stimulus effect of reconstruction will activate unused resources (Cuaresma et al., 2008; Hallegatte and Vogt-Schilb, 2019; Skidmore and Toya, 2002).

[10]To some degree, the increase in the number of recorded events may reflect improved measurement of natural disasters, particularly for small events.

markedly in climate disasters, the frequency of which tripled between 1960-79 and 2000-18.[11] Over 2000-18, natural disasters affected some 200 million people, costing on average more than 60,000 lives each year (Ritchie and Roser, 2020). In 2000-18, the average number of climate disaster episodes per year doubled relative to 1980-99, while the frequency of biological and geophysical disaster episodes increased by 40 and 10 percent respectively (**Figure 2**). Also in 2000-18, a natural disaster was 80 percent more likely to occur in LICs, and 35 percent more likely to occur in EMDEs, than in advanced economies.

Pandemics. Global pandemics such as the COVID-19 (2019-20) are rare events. There were only a few pandemics in the 20^{th} century including the Spanish flu (1918-19), Asian flu (1957-58), Hong Kong flu (1968-69), HIV/AIDS (1980s). Since 2000, the major epidemics were SARS (2002-03), swine flu (2009-10), MERS (2012), Ebola (2014-15), Zika (2015-16), which affected over 115 EMDEs and advanced economies (Dieppe, 2020). The COVID-19 (2019-20) outbreak has affected virtually all countries around the world and led to a sudden stop of the global economy.

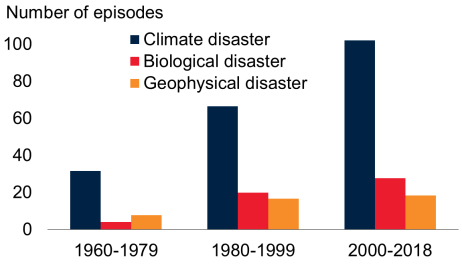
Regional distribution. SSA seems to be more exposed to natural disasters than other EMDE regions. In both 1980-99 and 2000-18, SSA had the highest frequency of natural disasters among EMDE regions. And in 2000-18, SSA experienced the largest increase in the frequency of natural disaster episodes relative to 1980-99. EAP and LAC were hit by at least 20 natural disaster episodes per year over 2000-18 (**Figure 2**). While climate events were relatively more frequent in East Asia and Pacific (EAP), Latin America and Caribbean (LAC), and SSA, historically, the largest number of biological disasters such as epidemic outbreaks occurred in SSA. The region least frequently affected by natural disasters was Middle East and North Africa (MNA).[12]

[11] Climate disasters refer to extreme weather events. Exposure to an adverse weather event will depend on the size of the population and total asset value located in at-risk areas. Vulnerabilities materialize when weather events hit exposed populations and assets, leading to economic losses (Cavallo and Noy, 2011; Costanza and Farley, 2007).

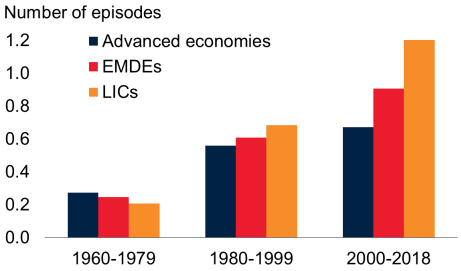
[12] Regions with large geographical areas can be exposed to more natural disasters than regions with small geographical areas.

Figure 2: **Episodes of natural disaster**

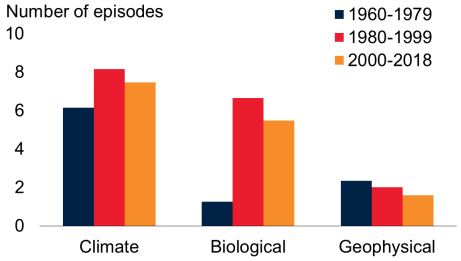
A. Average number of natural disaster episodes per year, by type



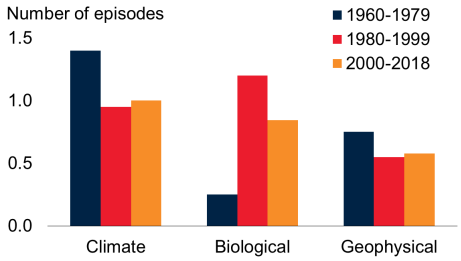
B. Average number of natural disaster episodes per country per year



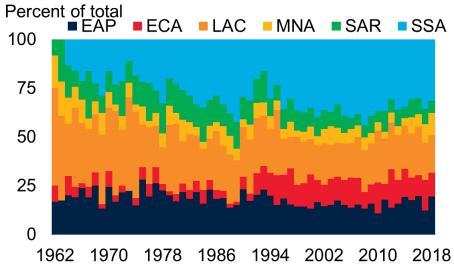
C. Average number of big natural disaster episodes per year, by type



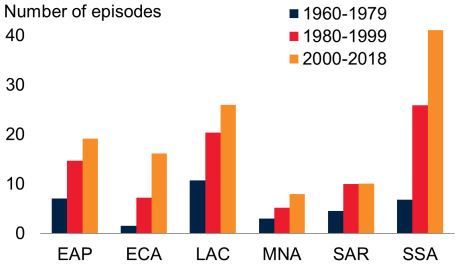
D. Average number of severe natural disaster episodes per year, by type



E. Share of natural disasters, by region



F. Average number of natural disaster episodes per year, by region



Source: EM-DAT; World Bank.
Note: Natural disasters include climate, biological, and geophysical disasters (EM-DAT). An episode dummy for a specific type of event is 1 if the event occurs at least once ($\geq$1) in a country-year pair and 0 otherwise. Big natural disasters and big wars are events that led to at least 10 deaths per million population. Severe natural disasters and severe wars are events that led to at least 100 deaths per million population. AEs=advanced economies, EMDEs=emerging market and developing economies (including low income countries), LICs=low income countries. EAP = East Asia and Pacific, ECA = Europe and Central Asia, LAC = Latin America and the Caribbean, MNA = Middle East and North Africa, SAR = South Asia, SSA = Sub-Saharan Africa. The sample includes 170 economies: 35 advanced economies and 135 EMDEs, of which 27 are low-income countries.

2.2 Wars

Apart from their direct toll on human life and welfare, wars can have major adverse effects on output and productivity (Abadie and Gardeazabal, 2003; Cerra and Saxena, 2008). Two types of wars are considered: intra-state and external armed conflicts (which include extra-state and inter-

state wars).[13] The destruction, disruption, and diversion effects of wars can cause sharp reductions in the labor force and physical capital, and dampen productive investment and innovation.[14]

2.2.1 Transmission channels of war shock to productivity

- **Reduced and disrupted labor forces.** Conflict-related losses of lives, coupled with population displacements, dampen output directly and disrupt the functioning of labor markets (Field, 2019).[15] Worldwide, about 68.5 million people—or 1 percent of the world's population—were in forcibly displaced situations in 2017 due to conflicts.[16] Moreover, many displaced persons are relatively well educated and skilled.

- **Weakened capital deepening.** Violent conflict destroys physical assets, holds back productive investment, provokes capital flight, and causes capital and finance to be diverted to less productive uses, including expenditure on armaments (Hutchinson and Margo, 2006). Wars have been estimated to have lowered the ratio of investment to GDP in Eastern Europe by about 5 percent over 1986-90 (Knight et al., 1996).

- **Hindered innovation.** Wars can have adverse effects on innovation and the adoption of technology.[17] They can lead to large-scale institutional disfunction, weakening of property rights, and sharp reductions in R&D investment, and they can also impede global value chains. All these effects can slow technological progress (Reynaerts and Vanschoonbeek, 2018; Rodrik, 1999). Wars can be particularly pernicious in LICs and FCV countries, partly because of their weak R&D capacity.

2.2.2 Stylized facts for wars

Intra-state wars in EMDEs, external wars in advanced economies. Between 1980-99 and 2000-18, the number of intra-state and external wars fell by almost 70 percent and 25 percent, respectively (**Figure 3**). EMDEs and LICs were mainly hit by intra-state conflicts, whereas advanced economies mainly experienced external wars (**Table 1**). A typical LIC was twice as likely to experience any kind of conflict as a typical EMDE. In 2000-18, the frequency of wars dropped in all regions. In 1960-2018, intra-state armed conflicts mainly occurred in SSA, whereas external wars mainly occurred in EAP and MNA.

[13] Intra-state wars are conducted between a state and a group within its borders. Extra-state wars take place between a system member and a non-state entity (not a system member). Inter-state wars are conducted between members of the interstate system.

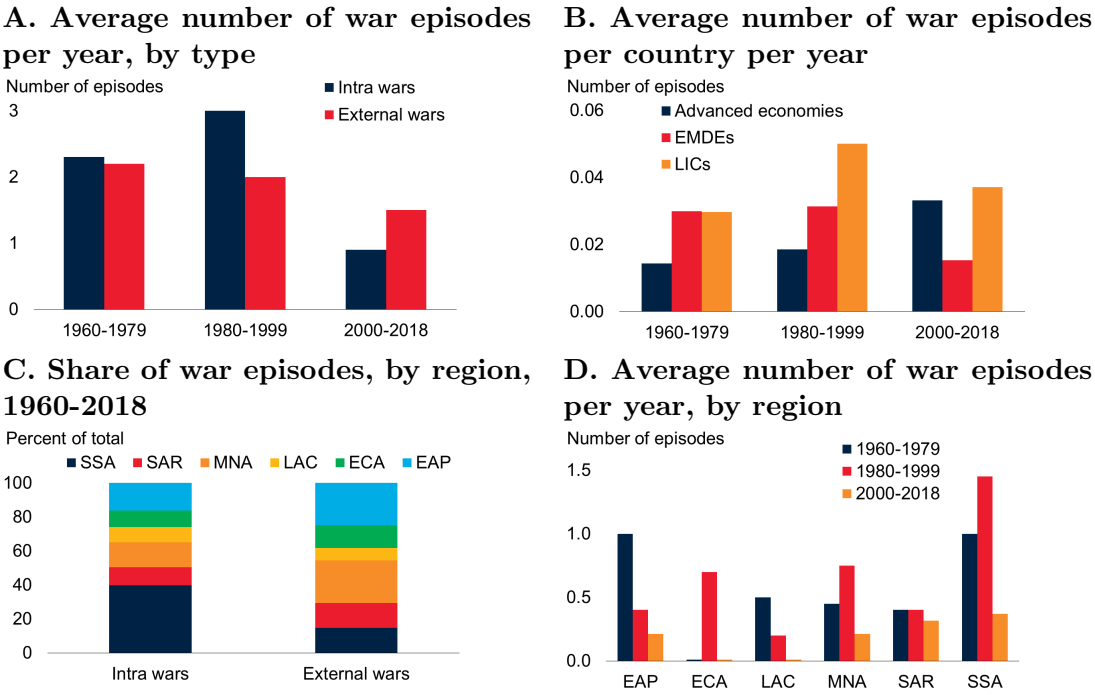
[14] See Easterly et al. (1993); Field (2008); Raddatz (2007); Rodrik (1999).

[15] For instance, during the 2007 post-election violence in Kenya, the labor force in the affected areas was reduced by as much as half owing to deaths, injuries, and lack of security for workers, and as a result wages rose by 70 percent (Ksoll et al., 2010).

[16] United Nations High Commissioner for Refugees (2018).

[17] In some cases, such as the Manhattan project undertaken during World War II, conflicts can stimulate innovation and R&D.

Figure 3: **Episodes of war**



Source: Correlates of War (COW); Peace Research Institute Oslo (PRIO); World Bank.
Note: Wars include intra-state and external (inter-state and extra-state) wars (COW and PRIO, Annex A). An episode dummy for a specific type of event is 1 if the event occurs at least once ($\geq$1) in a country-year pair and 0 otherwise. EMDEs = emerging market and developing economies (including low income countries), LICs = low income countries. EAP = East Asia and Pacific, ECA = Europe and Central Asia, LAC = Latin America and the Caribbean, MNA = Middle East and North Africa, SAR = South Asia, SSA = Sub-Saharan Africa. The sample includes 170 economies: 35 advanced economies and 135 EMDEs, of which 27 are low-income countries.

2.3 Financial crises

Financial crises sharply raise borrowing costs and worsen balance sheets. They have often led to severe economic contractions, with lasting corrosive effects on productivity levels and, in some cases, productivity growth (Cerra and Saxena, 2008, 2017; Blanchard et al., 2015). In the years since the global financial crisis and subsequent global recession of 2007-09, a broad range of countries has experienced significant and sustained slowdowns of productivity growth (Kose et al., 2020). Financial crises have often originated from the excessive accumulation of public or private sector debt and the associated development of mismatches in balance sheets. Debt accumulation increases risks to productivity growth not only by increasing the risk of crises in the short term, but also by tending to lead to the misallocation of resources towards low productivity sectors and depressing investment and technological innovation in the long term.[18]

Three broad types of financial crises are considered: sovereign debt crises, banking crises, and currency crises (**Annex A**). This section emphasizes the role of government debt accumulation, financial crises, and productivity losses, because of concerns about elevated debt levels in many countries.

[18]See Blanchard and Wolfers (2000); Bulow and Rogoff (1989); Hall (2014); Schnitzer (2002).

2.3.1 Transmission channels of financial crisis shock to productivity

Sovereign debt crises. These can be particularly detrimental to output and productivity. They generally originate from the excessive accumulation of government debt. Before a crisis occurs, higher government debt tends to increase the burden of interest payments in the government budget, and to raise borrowing costs, which may crowd out private investment (Kose et al., 2020; Oulton and Sebastiá-Barriel, 2017; Reinhart and Rogoff, 2010). Excessive growth of government debt erodes the country's ability to borrow, degrades private as well as public creditworthiness, and often leads to a curtailment of credit from institutional investors (Aguiar and Gopinath, 2006; Arellano, 2008). Elevated government debt can affect productivity growth via several channels:

- **Increased probability of financial crises.** Rising government debt will increase the risk of a financial crisis when it raises doubts about its sustainability. One of the ways this may occur is that higher debt may lead governments to adopt lower-cost but higher-risk debt management practices, including issuing debt with shorter maturities or denominated in foreign currency (Kalemli-Ozcan et al., 2018). Such practices can sharply raise risk premia on government debt, increasing borrowing costs and the risk of crisis (Arellano, 2008). Moreover, high sovereign debt constrains the ability of governments to exercise counter-cyclical fiscal policy (Eberhardt and Presbitero, 2015). Given the close interconnectedness between sovereign, banking, and foreign exchange sectors, sovereign debt crises can precipitate (or be caused by) banking and currency crises, compounding the damage to output and productivity.[19]

- **Misallocation of resources.** If used to fund productive investments with high rates of return, debt can have positive effects on productivity and growth. However, debt accumulation can impede productivity if it is associated with a misallocation of resources towards projects that yield only short-term returns or purely political gains.[20] Such misallocation is more likely if projects are being funded on unrealistic, possibly politically biased, expectations of rapid future growth (Claessens et al., 1997; Claessens and Kose, 2017, 2018).

- **Policy uncertainty.** High government debt can increase uncertainty about prospects for economic growth (Kose et al., 2020). For investors, the fear may be that high debt could eventually compel the government to hike taxes (including taxes on future investment returns), curtail growth-enhancing spending, crowd out productive investment (debt overhangs), or delay reforms that could support innovation and productivity growth.[21]

Banking and currency crises. Other types of financial crises, including systemic banking crises and currency crises, can also do lasting damage to productivity [22] The disruptions to financial intermediation that occur in banking crises impede investment, curb the funding of productivity-enhancing technologies and typically trigger recessions (De Ridder, 2017). In periods of protracted economic weakness, prolonged and elevated unemployment erodes human capital.[23] Because of

[19] See Aghion et al. (2000, 2009); Kalemli-Ozcan et al. (2018); Morris and Shin (1998).

[20] See Checherita-Westphal and Rother (2012).

[21] With regard to private sector debt, at the firm level, a large outstanding debt stock can weigh on investment and, hence, the productivity that technology embedded in this investment can generate (De Ridder, 2017). At the government level, debt service on high debt may crowd out other productivity-enhancing spending, including for education, health or infrastructure (Kose and Ohnsorge, 2019).

[22] See Blanchard et al. (2015); Cerra and Saxena (2017); Oulton and Sebastiá-Barriel (2017).

[23] Blanchard and Wolfers (2000); Furceri and Mourougane (2012a); Hall (2014).

their shorter duration, currency crises are typically less harmful to productivity than other financial crises (Cerra and Saxena, 2008).

2.3.2 Stylized facts for financial crises

Productivity losses during rapid debt accumulation episodes. Long-term productivity gains during rapid debt accumulation episodes have been considerably lower when these debt accumulation episodes were accompanied by financial crises. In a debt accumulation episode preceding a crisis, the cumulative growth rate of median productivity three years into the episode was 3 percent (**Figure 4**). This is statistically significantly less than the median increase during a debt accumulation episode that was not associated with a crisis (5 percent). The difference may be interpreted as a measure of the short-term damage to productivity from financial crises.

2.4 Comparing across types of adverse events

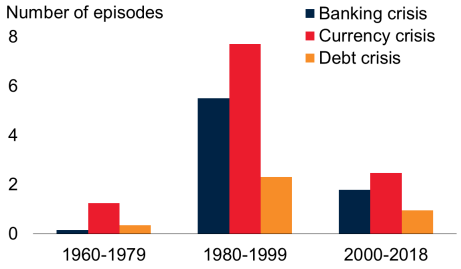
Climate disasters are the most frequent. Globally, natural disasters accounted for more than 90 percent of the recorded adverse events in 1960-2018 (**Table 1**). Over this entire sample, natural disaster episodes were about 25 times more frequent than wars despite the decline in natural disasters over the last 10 years (**Figure 1, 5**). Financial crises occurred twice as frequently as wars (**Figure 5**).

Wars are typically protracted. The average duration of wars was almost six years. Nearly half of financial crises last for more than two years. Natural disasters are typically much more short-lived (**Figure 5**). Some climate disasters last for just a few days while others, such as droughts, can last for several months. The cumulative loss of productivity can be larger if the adverse events last for a more extended period of time or if reconstruction efforts are delayed (Cerra and Saxena, 2008).[24]

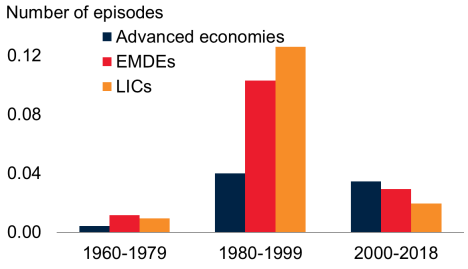
[24] Reconstruction pace may be slowed by financial, physical and transaction constraints (Hallegatte and Rentschler, 2018).

Figure 4: **Episodes of financial crisis**

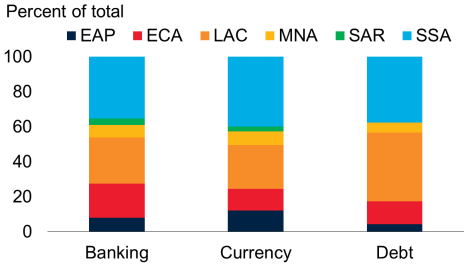
A. Average number of financial crisis episodes per year, by type (World)



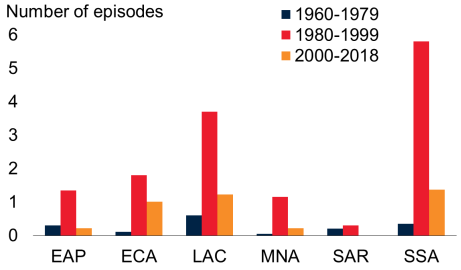
B. Average number of financial crisis episodes per country per year



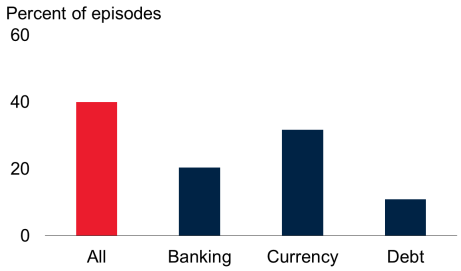
C. Share of financial crisis episodes, by region, 1960-2018



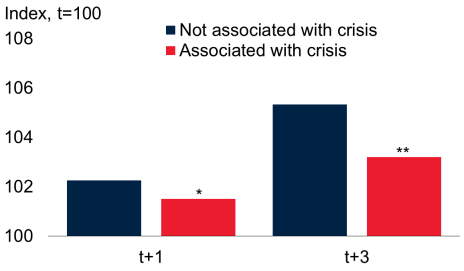
D. Average number of financial crisis episodes per year, by region



E. Total debt accumulation episodes around crises



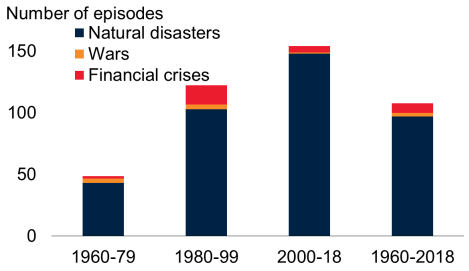
F. Cumulative productivity gains during episodes of rapid debt accumulation



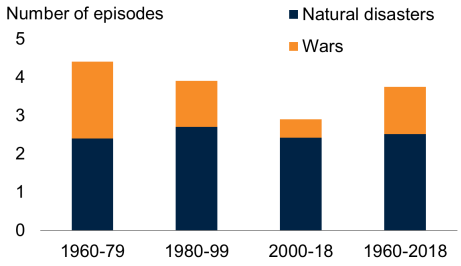
Source: Laeven and Valencia (2018); World Bank.
Note: Financial crisis episodes include banking crisis, currency crisis, and sovereign debt crisis (Laeven and Valencia 2018, Annex A). An episode dummy for a specific type of event is 1 if the event occurs at least once ($\geq$1) in a country-year pair and 0 otherwise. EMDEs = emerging market and developing economies (including low income countries), LICs = low income countries. EAP = East Asia and Pacific, ECA = Europe and Central Asia, LAC = Latin America and the Caribbean, MNA = Middle East and North Africa, SAR = South Asia, SSA = Sub-Saharan Africa. The sample includes 170 economies: 35 advanced economies and 135 EMDEs, of which 27 are low-income countries.
A-D. Debt crisis refers to sovereign debt crisis.
E. Share of total (government and private) debt accumulation episodes associated with financial (banking, currency, debt) crises.
F. ** and * indicates 5, and 10 percent significance levels.

Figure 5: **Episodes across different types of events**

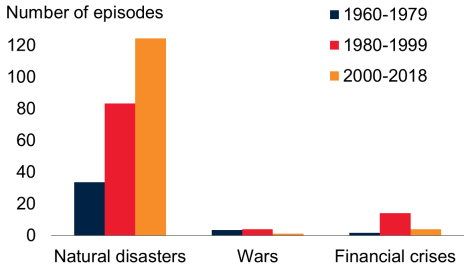
A. Average number of episodes per year



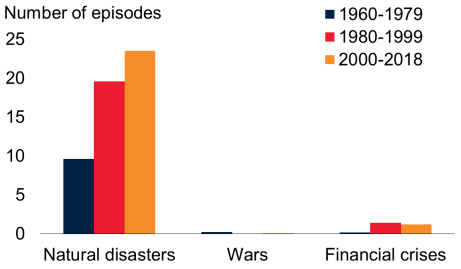
B. Average number of severe natural disaster and severe war episodes per year



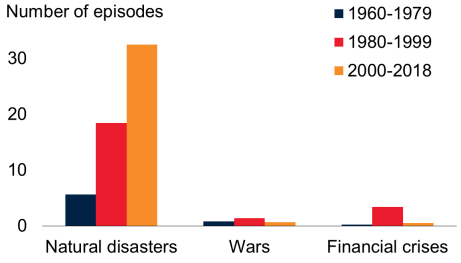
C. Average number of episodes per year in EMDEs



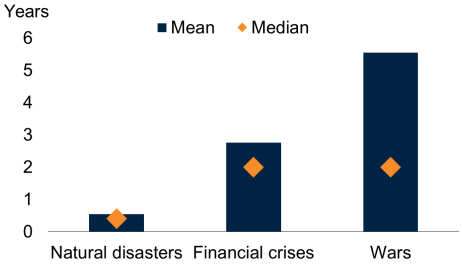
D. Average number of episodes per year in AEs



E. Average number of episodes per year in LICs



F. Average duration



Source: Correlates of War (COW); EM-DAT; Laeven and Valencia (2018); Peace Research Institute Oslo (PRIO); World Bank.
Note: Natural disasters include climate, biological, and geophysical disasters (EM-DAT). Wars include intra-state and external (extra-state and inter-state) wars (COW and PRIO). Financial crises include banking crisis, currency crisis, and sovereign debt crisis (Leaven and Valencia 2018). Definitions are in Annex A. An episode dummy for a specific type of event is 1 if the event occurs at least once ($\geq$1) in a country-year pair and 0 otherwise. Severe natural disasters and severe wars are events that led to at least 100 deaths per million population. The sample includes 170 economies: 35 advanced economies and 135 EMDEs, of which 27 are low-income countries.
B. Severe natural disasters and severe wars are defined as events that led to at least 100 deaths in million population.

3 Empirical strategy

3.1 Data

This study combines data from various sources for the period 1960-2018. Natural disasters data include climate (droughts, floods, cyclones), biological (diseases, epidemics, insect infestations) and

geophysical (earthquakes, tsunamis, volcanoes) disasters. Wars include internal (intra-state) and external (inter- and extra-state) armed conflicts that are identified using the Correlates of War (COW) and Peace Research Institute Oslo (PRIO) databases. Financial crises include banking, currency and debt crises and are based on the Laeven and Valencia (2018) database. For additional details on the definition of the events and data, we refer the reader to **Annex A**.

3.2 Methodology

To assess the effects of adverse events on productivity, the local projection method (LPM) is used, with country productivity level, measured as output per worker, as the dependent variables (Jordà et al., 2013; Jordà, 2005).[25] The LPM approach provides an estimate of the response of labor productivity (and TFP) to adverse events over various horizons. It also helps to identify key transmission channels, assess how countries' resilience to adverse events has changed over time and analyze the role of policies in mitigating their effects. The advantage of this approach is that it avoids the problem of dimensionality inherent in other approaches such as vector autoregressions.[26] However, it does not directly take into account the severity of the adverse event.

The dependent variable is the cumulative change in labor productivity, TFP or output levels between horizons $t-1$ and $t+h$, measured as difference in the natural logarithms $y_{t,j}$. The explanatory variables include the event dummy and controls. For a specific type of event, the explanatory variable of interest is an episode which equals 1 if the event occurred at least once in a particular country in a year and 0 otherwise. The baseline model is given by

$$\begin{aligned} y_{t+h,j} - y_{t-1,j} = \alpha_{(h),j} + \tau_{(h),t} + \beta_{(h)} E_{t,j} + \sum_{s=1}^{p} \gamma_{l(h),s} E_{t-s,j} \\ + \sum_{s=1}^{h-1} \gamma_{f(h),s} E_{t+h-s,j} + \sum_{s=1}^{p} \delta_{(h),s} \Delta y_{t-s,j} + u_{(h)t,j} \end{aligned} \tag{1}$$

where $h = 0, 1, 2, \cdots$ is the horizon, $\alpha_{(h),j}$ and $\tau_{(h),t}$ are country j and time fixed effects, and $u_{(h)t,j}$ is an error term. The coefficient of interest $\beta_{(h)}$ captures the dynamic multiplier effect (impulse response) of the dependent variable with respect to the event dummy variable $E_{t,j}$. The number of lags for each variable is denoted by p and set to 1 for the estimation. The specification controls for (i) country-specific trends, (ii) lagged event dummies, (iii) future values of the event dummy between time t and $t+h-1$ to correct for possible forward bias (Teulings and Zubanov, 2014), and (iv) past changes $\Delta y_{t-s,j}$.

The event dummies are lagged to help attenuate the potential endogeneity bias caused by contemporaneous interactions between productivity (TFP or output) and crises. In some cases, weak productivity accompanied by a sharp decline in output can trigger financial crises and wars. To guard against such possible endogeneity or reverse causation between productivity and the event,

[25] Labor productivity is measured as output per worker, with the number of employees used as the unit of labor input. This has the advantage of wide availability across countries. Its disadvantage rests in the failure to account for the quality and intensity of labor input.

[26] Vector autoregressions approaches entail modeling and estimating a large number of time series, whereas LPM focuses on the dynamics of the variable of interest—productivity in this case.

lagged productivity is used as a control. The regressions are estimated separately for natural disasters, wars, and financial crises over 1960-2018. Additional controls for country-specific interactions and non-linear effects such as the presence of a positive fiscal space in a country are also included in alternative specifications.

4 Results

This section analyzes the effects of natural disasters, wars and financial crises on both labor productivity and TFP.

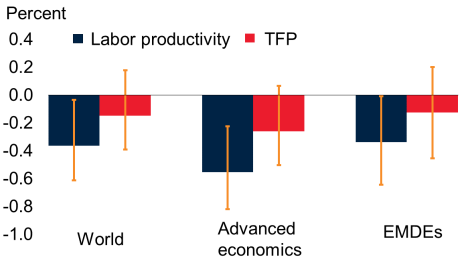
4.1 Impacts of natural disasters

Natural disasters can lead to significant contemporaneous losses in labor productivity in both advanced economies and EMDEs (Figure 6). The estimates indicate that immediately after a natural disaster, labor productivity tended to decline by 0.5 and 0.3 percent in advanced economies and EMDEs, respectively. These results are consistent with those found in the literature (Dell et al., 2012; Fomby et al., 2013; Strömberg, 2007). As well as the destruction of the capital stock, which weakens labor productivity, natural disasters also adversely affect TFP (Skidmore and Toya, 2002). However, the magnitude of the estimated effect of natural disasters on TFP may be expected to be smaller than that on labor productivity, because of the effect on the latter of the loss of physical capital. Indeed, the estimates indicate that natural disasters led to a 0.3 percent decline in TFP in advanced economies, in the first year of the disaster, with no significant effect in EMDEs. This may reflect possible offsetting productivity gains resulting from investment by governments and firms in new and more technologically advanced capital—investment induced by the natural disaster—leading to improvements in both TFP and labor productivity (Hallegatte and Dumas, 2009; Skidmore and Toya, 2002).

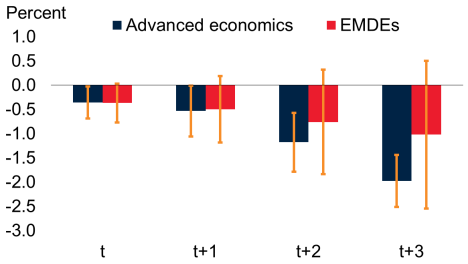
Climate disasters. Among the different types of natural disasters, climate disasters have been particularly detrimental in terms of lost labor productivity. The estimates for both advanced economies and EMDEs indicate that climate disasters contemporaneously reduced labor productivity by about 0.5 percent and have persistent effects in both advanced economies and EMDEs. For EMDEs however, the estimated longer-term drag on productivity is smaller and subject to a wider margin of error. In fact, many previous studies have found that economies hit by climate disasters have been able to recover, especially after smaller-scale events (Hallegatte et al., 2007; Loayza et al., 2012).

Figure 6: **Estimated effects of natural disaster episodes on productivity**

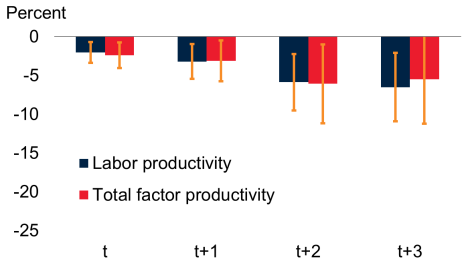
A. Contemporaneous effect of natural disaster episodes on labor productivity and TFP



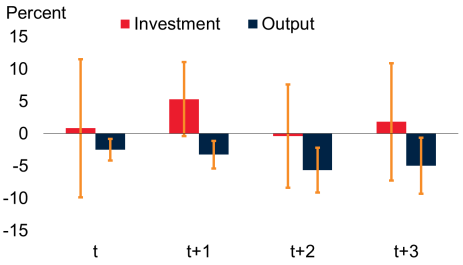
B. Effect of climate disaster episodes on labor productivity



C. Effects of severe climate disaster episodes on labor productivity and TFP



D. Effects of severe climate disaster episodes on labor investment and output



Source: EM-DAT; World Bank.
Note: Natural disasters include climate, biological, and geophysical disasters (EM-DAT, Annex A) An episode dummy for a specific type of event is 1 if the event occurs at least once ($\geq$1) in a country-year pair and 0 otherwise. EMDEs = emerging market and developing economies (including low income countries). Blue (and red) bars indicate the average impact of the event for each group and orange lines represent the 90 percent significance range.
C-D. Severe climate disasters are defined as events that led to at least 100 deaths in million population.

Threshold effects and severe climate disasters. Previous studies have distinguished among natural disasters in terms of their scale, using different thresholds, and found that the estimated effects on productivity and output are dependent on the size of the natural disaster (Annex A).[27] Larger natural disasters have been found to have more severe immediate negative consequences for the economy (Fomby et al., 2013). Smaller events have been shown to have less persistent effects and even positive effects over the longer term (Loayza et al., 2012; Cavallo et al., 2013). The literature finds that severe disasters have disproportionately larger economic impacts due to non-linear effects on labor force participation and human capital, particularly amongst younger workers (Cavallo et al., 2013; Hallegatte and Przyluski, 2010; Loayza et al., 2012). Furthermore, the cumulative loss of productivity tends to be larger if the disaster lasts for a more extended period—as is the case with biological disasters—or if reconstruction efforts are delayed (Sawada, 2007; Cerra and Saxena, 2008).[28] Some studies suggest that the long-run costs of natural disasters

[27]EM-DAT data can suffer from selection biases leading to a non-linear link between physical intensity and (direct) asset losses (Felbermayr and Gröschl, 2014).

[28]The pace of reconstruction may be slowed by financial, physical and transaction constraints (Hallegatte and Rentschler, 2018).

are mainly driven by uninsured losses, subsequent institutional instability, or regime changes.[29] This is supported by the analysis here, which suggests that larger shocks can have a positive effect on productivity in advanced economies, which likely benefit from better emergency response, more effective reconstruction plans, and deeper insurance markets (Annex A).

In the analysis here, severe climate disasters are defined as those that caused at least 100 deaths per one million inhabitants. The results support the intuition that severe climate disasters have larger and more persistent effects on productivity in EMDEs than less severe ones. Labor productivity fell initially by about 2 percent and more than 7 percent below baseline, three years after a severe climate disaster (Figure 6). The estimates show that lower labor productivity is mainly accounted for by weaker total factor productivity rather than reduced investment.[30] Possibly because after a severe disaster, firms delay or trim down RD spending, which impedes the creation, transfer, and adoption of new technologies, and hinders global value chains. On the other hand, overall investment may remain more resilient as reconstruction spending partly offsets some reduction in other types of capital spending.

The effects of biological and geophysical events are found to be not statistically significant. However, the estimates are for the average event, which could be localized or for other reasons affect only a limited number of people. Large biological or geophysical events may have large negative effects on productivity, including by constraining economic activity and human interaction, disrupting global value chains, and depressing demand, as exemplified by the COVID-19 outbreak.

Effects of epidemics. Epidemics lead to large and lasting negative effects on labor productivity.[31] There were five epidemics during the period 2000-2018: SARS (2002-03), Swine flu (2009), MERS (2012), Ebola (2014-15), and Zika (2015-16). These four major epidemics, excluding the Swine flu since it coincides with global financial crisis to avoid compounding effects, lowered labor productivity initially by 1 percent, and by 4 percent cumulatively after three years (Dieppe, 2020). These severe epidemics seem to adversely affect labor productivity primarily through investment, which declined by 9 percent after three years due increased uncertainty.

Cascade effects. Natural disasters can trigger other types of adverse events such as debt crises and wars, thus compounding the effects on productivity. Studies show that countries hit by major disasters can experience a sharp widening of the budget deficit, which can then increase the likelihood of a sovereign debt crisis. Moreover, natural disasters can widen inequalities and exacerbate political tensions in affected countries. (Besley and Persson, 2011) estimated, for a sample of 97 countries in the period 1950-2005, that natural disasters increased the probability of wars by about 4 percentage points.

LICs. Fragile states and LICs are among the countries most exposed to natural disasters (**Table A3**, Figures 2).[32] Although land-locked LICs have tended to experience fewer natural disasters

[29] For example, some have found that the adverse macroeconomic effects of natural disasters dissipate after five years and that climate disasters explain a very small portion of the variance in real per capita GDP (Raddatz, 2007).

[30] The impact on investment can be noisy due to possible mismeasurements in capital stock.

[31] Epidemics are different than typical biological disasters in the sense that they last longer and are accompanied by elevated uncertainty.

[32] There are 41 natural disasters episodes per country in LICs compared to 34 in EMDEs in the whole sample

than non-land-locked LICs, the impacts of such events on LICs have generally been considerably larger than in other income group economies, with more deaths as a percentage of the population and larger losses of output. This is partly because a larger proportion of workers are in primary sectors—agriculture and mining—which are more susceptible to natural disasters. Moreover, infrastructure in LICs tends not to be as robust as in advanced economies. LICs also often lack the ability to quickly cope with natural disasters and thus tend to suffer additional losses stemming from disease and displacement (Kahn, 2005). LICs that are more often hit by natural disasters tend to have lower labor productivity and TFP level than LICs that are less frequently hit by them. The disruptive effects of natural disasters may substantially delay—or even derail—the convergence process in LICs.

4.2 Impacts of wars

The analysis here focuses on the effects of wars on EMDEs.[33]

Intra-state wars. On average, EMDEs that experienced intra-state wars are estimated to have suffered a reduction in labor productivity of roughly 5 percent three years after the beginning of the war (**Figure 7**). Although there was some recovery subsequently, the loss was still around 3 percent after five years.[34] Significant negative effects on TFP occurred with more of a time lag. Based on other research, the loss of TFP may have been partly the result of negative effects on health, especially of children, disruptions to education, and weakened trade (Ades and Chua, 1997; Akresh et al., 2012; Collier and Hoeffler, 2004). The decline in TFP reaches around 6 percent three years after the beginning of the war.

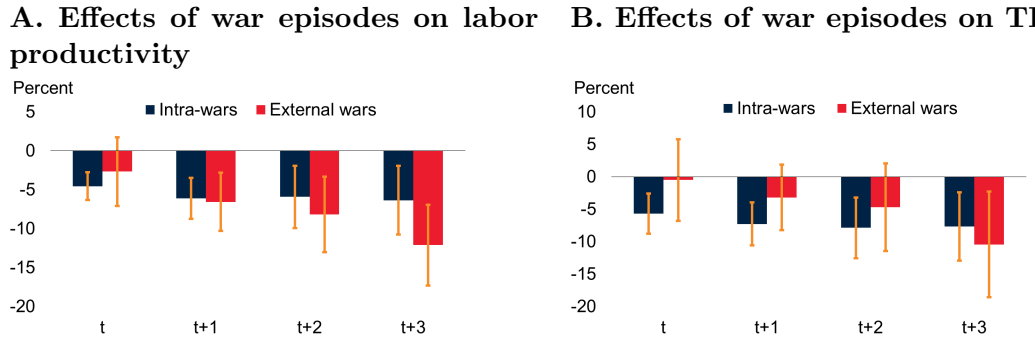
External wars. These refer to both inter-state and extra-state wars combined. The losses from these two kinds of external wars have been much more pronounced than those from intra-state wars. This may be accounted for partly by the fact that international trade and FDI have been found to decline more in times of external conflict (Bayer and Rupert, 2004; Busse and Hefeker, 2007). Three years after the onset of an external war in an EMDE, the estimated decline in labor productivity exceeds 12 percent on average. The estimated negative effects on TFP are, not surprisingly, somewhat smaller than on labor productivity given that labor productivity, but not TFP, is affected by the loss of capital (Hutchinson and Margo, 2006). The estimated decline in TFP after three years is 10 percent, with only a modest subsequent recovery (**Figure 7**).

(**Table A3**).

[33] The focus here is on EMDEs since there have in recent years been no civil wars in advanced economies and the estimates suggest that the effects of inter-state wars for advanced economies are ambiguous.

[34] Easterly et al. (1993) found, for 80 countries during the 1970s and 1980s, that war-related casualties per capita is correlated significantly negatively (-0.3) with GDP per capita growth. Rodrik (1999) extended this study and found larger declines in GDP per capita growth for countries with high ethnolinguistic fragmentation.

Figure 7: **Estimated effects of war episodes on productivity in EMDEs**



Source: Correlates of War (COW); Peace Research Institute Oslo (PRIO); World Bank.
Note: A.B. Wars include intra-state and external (extra-state and inter-state) wars (COW and PRIO, Annex A). An episode dummy for a specific type of event is 1 if the event occurs at least once (≥1) in a country-year pair and 0 otherwise. Blue and red bars indicate the average effect of the event for each horizon and orange lines represent the 90 percent significance range.

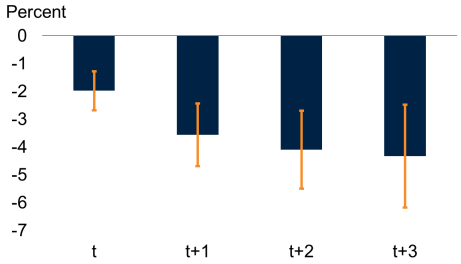
4.3 Impacts of financial crises

Financial crises tend to lead to large and long-lasting productivity losses. The estimates indicate that in the year of the onset of a financial crisis, labor productivity globally has declined on average by about 2 percent (**Figure 8**). The estimated decline three years later is 4 percent. The estimated effects are more modest for EMDEs than for advanced economies. For advanced economies, the decline in labor productivity three years after the onset of the crisis is around 6 percent, compared to around 3 percent in EMDEs. The larger productivity fall in advanced economies could reflect the larger size and economic importance of financial markets in these economies. The large initial productivity losses associated with financial crises are consistent with the literature.[35] The estimates showing sustained damage to productivity are consistent with the years of subpar growth since the 2008-09 global recession, as well of the sharp reduction of economic growth and investment in Asia following the region's 1997-98 financial crisis (Barro, 2009; Cerra and Saxena, 2008). Sovereign debt crises have typically been associated with falls in labor productivity and TFP of around 7.5 percent and 4.5 percent, respectively, three years after a default or debt restructuring. Banking and currency crises have tended to be associated with subsequent reductions in labor productivity of between 5-7 percent in EMDEs after three years. This is consistent with other studies in the literature, although some suggest that the effects of banking crises are often short-lived.[36] These adverse effects on productivity appear to be larger in advanced economies, again possibly because of their larger and more economically important financial markets. However, advanced economies may have more competitive banking systems, which may reduce the likelihood of experiencing a financial crisis relative to EMDEs (Demirgüç-Kunt and Levine, 2001; Beck et al., 2006).

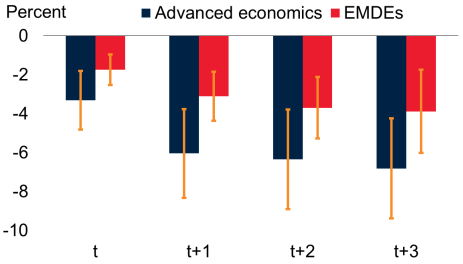
[35] See Ball (2014); Cerra and Saxena (2008); Furceri and Mourougane (2012b); Hutchison and Noy (2005).
[36] See Crafts (2013); Demirgüç-Kunt et al. (2006); Morris and Shin (1998); Reinhart and Rogoff (2009).

Figure 8: **Estimated effects of financial crisis episodes on labor productivity**

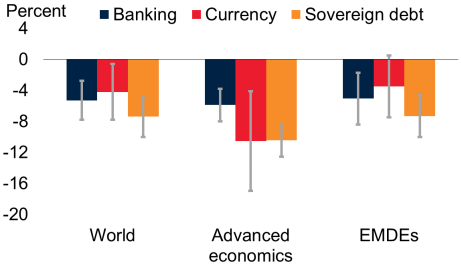
A. Effects of financial crisis episodes on labor productivity, world



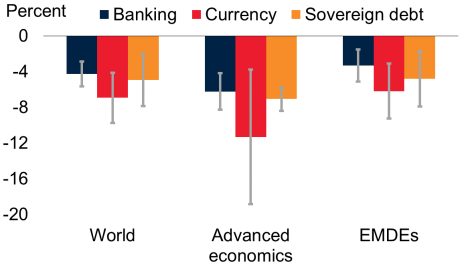
B. Effects of financial crisis episodes on labor productivity



C. Change in labor productivity three years after financial crisis episodes



D. Change in TFP three years after financial crisis episodes



Source: Laeven and Valencia (2018); World Bank.
Note: Financial crisis episodes include banking crisis, currency crisis, and sovereign debt crisis ((Laeven and Valencia, 2018), Annex A). An episode dummy for a specific type of event is 1 if the event occurs at least once (≥1) in a country-year pair and 0 otherwise. EMDEs=emerging market and developing economies (including low income countries).
A.B. Blue bars indicate the average impact of the event for each horizon and orange lines represent the 90 percent significance range.
C.D. Blue, red, and orange bars indicate the average impact of the event for each financial crisis three years after the onset of the crises and gray lines represent the 90 percent significance range.

Compounding effects of twin crises. Consistent with some of the literature, currency crises in EMDEs were found to lead to smaller labor productivity losses than debt and banking crises. However, sovereign debt crises can exacerbate the effects of currency or banking crises. Thus, the current estimates for EMDEs find that the effect of twin crises, consisting of simultaneous banking and currency crises, has been more severe than the sum of the effects of separate banking and currency crises.[37] While banking crises have been associated with a contemporaneous decline in labor productivity of around 2 percent, and currency crises with a decline of 0.2 percent, twin banking-currency crises have been associated with a 3.5 percent decrease, suggesting that the interaction of shocks in a combined crisis substantially compounds the harm that ensues.

4.3.1 Comparison across types of events

From a public policy perspective, the allocation of budgetary resources to disaster prevention efforts should depend on the relative costs of the expected output losses and other problems associated

[37] Cerra and Saxena (2008); Kaminsky and Reinhart (1999) find larger effects. However, Hutchison and Noy (2005) find no additional (marginal) negative impacts above and beyond the combined effect of the two crises.

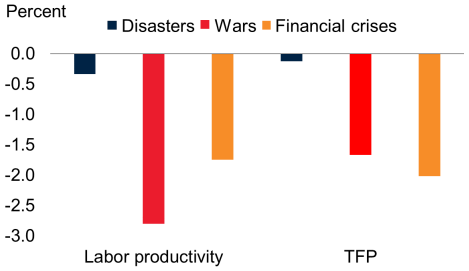
with the events, as well as the effectiveness of the mitigation efforts. However, comparing the costs of different types of shocks is challenging, since the identification of events depends on the threshold used for metrics such as the size of financial losses and the number of casualties. Moreover, the impact of future events may differ from past ones of the same type because of changing socio-economic environments. In EMDEs, according to the estimates, wars have been about 10 times more detrimental to productivity on impact than natural disasters, and 1.5 times more detrimental than a financial crisis. An average financial crisis has thus tended to reduce productivity much more than a typical natural disaster (**Figure 9**). The results, which are broadly in line with the literature, show that on average financial crises induce a loss of about 2 percent in output per capita one year after their onset. This is twice the magnitude of the one-year productivity loss following an average natural disaster. Over a longer horizon, according to estimates from the literature, wars appear to be most disruptive at the 5-year horizon, reducing output per capita by an average of about 9 percent. However, there is a wide range of estimates, with some as high as 20 percent (Barro, 2009). This may stem from differences in the criteria used to identify adverse events such as definitions, thresholds for damage and casualties, country coverage, the sample period, and estimation approach (e.g., counterfactual analysis, panel regressions, local projection). When estimating the overall impact of different types of disasters and considering policy design, it is critical to consider not only the average impact of an average shock but also the frequency of different events (**Figure 10**). While climate disasters tend to have small effects on productivity, they are much more frequent than financial shocks or wars; they also typically affect the poorest countries most. Because of the relatively high frequency of climate disasters in EMDEs, the expected annual loss of labor productivity resulting from them is well above the expected loss from financial crises. On the other side, wars and epidemics tend to be infrequent and to affect only a few countries, so that the average expected losses are small. However, the effects of infrequent wars and epidemics on the countries affected tend to be severe, which underscores the importance of implementing proactive policies to address tail risk events. These results are useful to gauge where risks are relatively high and provide guidance to prioritize mitigation policies.

4.3.2 Severe adverse events

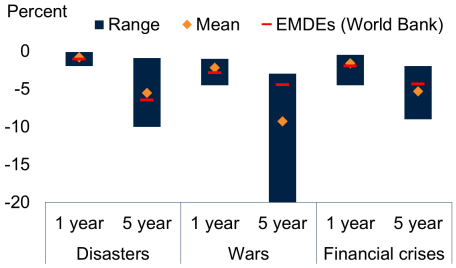
Rare and severe events may have disproportionately large impacts on the afflicted countries compared to the small and frequent ones (Hallegatte and Przyluski, 2010; Loayza et al., 2012). Large-scale natural disasters tend to cause larger damage to capital, employment and output. Severe wars and intense armed conflicts with large death tolls also cause outsized damage to physical capital, labor and output (Hutchinson and Margo, 2006). The negative effects of severe events on labor force participation and human capital are particularly more acute among the most vulnerable population groups such as women and younger workers.

Figure 9: **Comparison of estimated effects in EMDEs**

A. Initial impacts of natural disaster, war and financial crisis episodes on EMDE productivity



B. Estimated effects of natural disasters, wars and financial crises on output per capita from the literature



Correlates of War (COW); EM-DAT; Laeven and Valencia (2018); Peace Research Institute Oslo (PRIO); World Bank.
Note: Natural disasters include climate, biological, and geophysical disasters (EM-DAT). Wars include intra-state and external (extra-state and inter-state) wars (COW and PRIO). Financial crises include banking crisis, currency crisis, and sovereign debt crisis (Leaven and Valencia 2018). Definitions are in Annex A. An episode dummy for a specific type of event is 1 if the event occurs at least once ($\geq$1) in a country-year pair and 0 otherwise.
A. Blue, red and orange bars indicate the average contemporaneous effect of the event.
B. The range of estimates is from the literature.

4.3.3 Global adverse events

Some large-scale adverse events affect many countries simultaneously. The effects of these global shocks have been amplified through various propagation channels—financial markets, value chains, transport services, trade—as economies have become more integrated. This was exemplified by the 2008 global financial crisis, which started in the U.S. subprime sector and spilled over to global financial markets and economies around the world and was followed by a global productivity slowdown. Large-scale natural disasters such as the COVID-19 pandemic will likely leave deep scars on productivity and output via a dislocation of labor, a tightening of credit, a disruption of value chains and a decline in innovation in addition to triggering financial crisis (Dieppe, 2020).

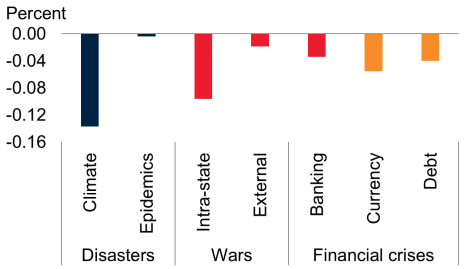
The recent policies implemented in response to COVID-19 show that quick interventions by international, national, and local authorities with various policies are essential as global adverse events are likely to occur in the future and have lasting negative effects on productivity. They underscore the need for countries to be better prepared to cope with global shocks. Policy support can help to mitigate some of the scarring effects of these global shocks.

5 What policies can mitigate the effects of adverse events?

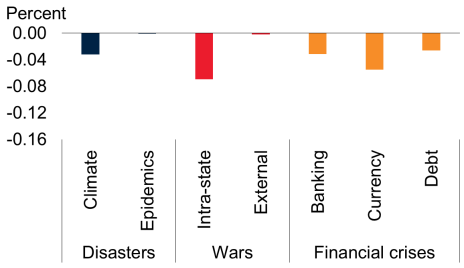
Policies can help to reduce the risks of some natural disasters, including through actions to tackle global warming, better protect vulnerable areas and populations, and reduce the likelihood of wars and financial crises. Mitigation policies are likely to require adequate fiscal space and involve appropriate structural reforms.

Figure 10: **Productivity loss in EMDEs, scaled by event frequency**

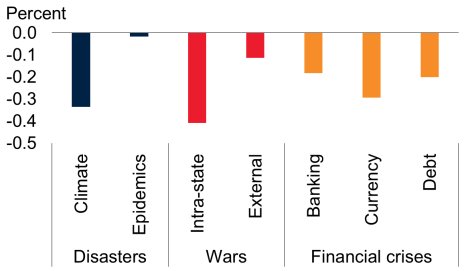
A. Contemporaneous impacts of natural disaster, war and financial crisis episodes on labor productivity



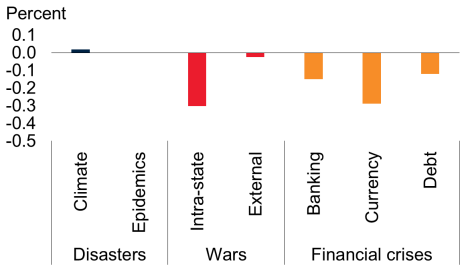
B. Contemporaneous impacts of natural disaster, war and financial crisis episodes on TFP



C. Average cumulative loss of labor productivity, three years after natural disaster, war and financial crisis episodes



D. Average cumulative loss of TFP, three years natural disaster, war and financial crisis episodes



Correlates of War (COW); EM-DAT; Laeven and Valencia (2018); Peace Research Institute Oslo (PRIO); World Bank.
Note: Natural disasters include climate, biological, and geophysical disasters (EM-DAT). Wars include intra-state and external (extra-state and inter-state) wars (COW and PRIO). Financial crises include banking crisis, currency crisis, and sovereign debt crisis (Laeven and Valencia, 2018). Definitions are in Annex A. An episode dummy for a specific type of event is 1 if the event occurs at least once ($\geq$1) in a country-year pair and 0 otherwise.
A-D. Blue, red and orange bars indicate the average impact of the event, which is the effect of event multiplied by the probability of that particular event in EMDEs.

Addressing vulnerabilities and mitigating the effects of adverse events. In the aftermath of large-scale destructive events like the COVID-19, wars and natural disasters, emergency response and reconstruction can help prevent lasting productivity losses. Countries vulnerable to natural disasters could bolster investment in resilient infrastructure, strengthen healthcare systems, and foster climate-friendly innovation.[38] They could also strengthen social safety nets. In LICs, in particular, fiscal buffers might be limited, so foreign aid flows could be helpful by complementing domestic resources. If appropriate, populations and critical infrastructures could be relocated to areas less prone to natural disasters. Regulatory reforms and macro-prudential policies to monitor and address, in a timely manner, systemic banking risks, and debt and external vulnerabilities, can reduce the likelihood of financial crises.

Improving institutions and the business climate. Structural reforms that raise the quality

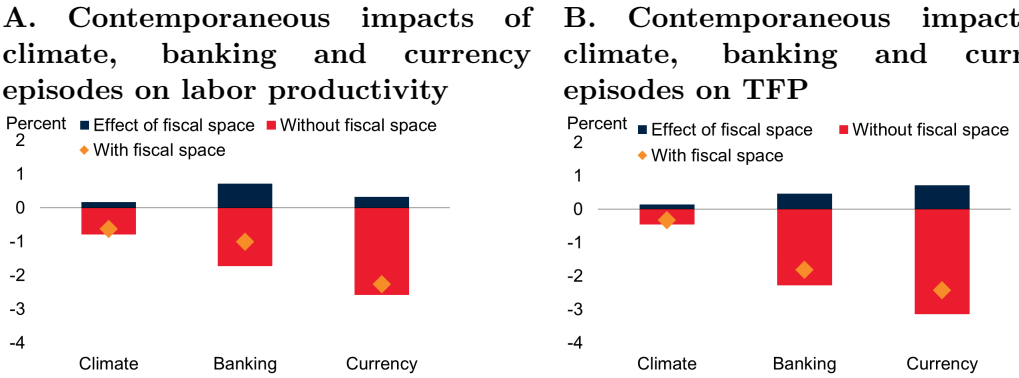
[38] Reducing those vulnerabilities is efficient in economic terms as each dollar invested in resilience tends to generate four dollars in benefits (Hallegatte et al., 2019).

and effectiveness of governance and improve the business climate can reduce the likelihood of some adverse events and also help to limit the damage caused by those that occur. Governments that have improved labor and product market flexibility, strengthened legal systems and property rights, fostered effective competition, and addressed inequality will have laid the foundations for more effective private sector adjustment to adverse events (Anbarci et al., 2005). Good regulations and institutions can improve risk-sharing and the prevention and mitigation of financial crises and some natural disasters. They can also reduce the probability of wars, which can be rooted in inequalities, unresolved grievances, and greed (Collier and Hoeffler, 2004). Reform-driven productivity gains critically depend on the sustainability, timing, size, mix, and duration of such interventions.

Building fiscal space. Emergency responses and reconstruction efforts after wars or natural disasters can be costly. Deep financial crisis may require a sizable fiscal response as well—several advanced economies and EMDEs implemented fiscal stimulus to counter the negative consequences of the 2008 global financial crisis. This underscores the importance of having adequate fiscal buffers to be able to counter negative shocks as well as effective, transparent governance to ensure that funds are spent effectively and in appropriate amounts (Reinhart and Rogoff, 2010; Oulton and Sebastiá-Barriel, 2017; Hallegatte and Rentschler, 2018).[39] Fiscal space may be defined as a government's ability to fund expansionary fiscal policies without undermining sustainability of public finances. When the previously described LPM regressions were amended to introduce an estimate of fiscal space as a variable (Jordà, 2005; Duval and Furceri, 2018), it was found that countries with positive fiscal space tended to experience smaller detrimental effects on productivity after banking or currency crises, or climate disasters (**Figure 11**). The estimates suggest that positive fiscal space provides support to productivity of around 0.9 percent in the case of currency crises, and 0.8 percent in banking crises. Positive fiscal space is also estimated to help alleviate the detrimental effects of climate disasters on productivity, although to a smaller degree. There are similar effects on TFP. In addition, fiscal space is found to help reduce the likelihood of adverse financial events.

[39] Not only do needs for emergency and reconstruction expenditures rise after natural disasters but also government revenues tend to fall.

Figure 11: **Productivity loss taking account of fiscal space in EMDEs**



Source: EM-DAT; Laeven and Valencia (2018); World Bank.
Note: Climate disasters (EM-DAT), banking and currency crises (Laeven and Valencia, 2018) are defined in Annex A. An episode dummy for a specific type of event is 1 if the event occurs at least once (≥1) in a country-year pair and 0 otherwise.
A.B. Blue bars indicate the impact of having a fiscal space on the effect of the adverse events on productivity (effect of fiscal space); red bars represents the gross effect of adverse events on productivity without the fiscal space impact (without fiscal space); and orange mark shows the average net effect of adverse events for the countries which has fiscal space (with fiscal space).
B. TFP = total factor productivity.

6 Conclusions

Major adverse events—natural disasters, wars, and financial crises—can have long-lasting negative effects on productivity. This paper has presented a comprehensive analysis of the effects of adverse events on labor productivity and TFP. It explored the channels through which events can erode productivity, how different types of events affect productivity differently and the extent to which they have larger effects on EMDEs and LICs. The paper also explored the role that policies can play in mitigating these adverse effects. The results suggest that wars tend to be highly damaging to productivity. In addition to their human toll, wars destroy physical capital and disrupt production and trade. Intra-state and external wars are estimated to have lowered labor productivity after three years by about 6 and 12 percent, respectively. The estimated effect of natural disasters on labor productivity and TFP is smaller, but such events are the most frequent and are therefore a substantial hindrance to productivity. Negative effects from natural disasters have varied by type and also across countries, with LICs being particularly vulnerable, so that there have been important adverse effects on poverty. Productivity is also highly vulnerable to financial stress, particularly when accompanied by a rapid build-up of government debt. Severe disasters, such as the COVID-19 pandemic, not only dislocate labor and supply chains, but can also trigger financial stress with severe lasting effects on productivity. Epidemics that occurred since 2000 have lowered labor productivity by a cumulative 4 percent after three years, mainly through their adverse impact on investment and the labor force. In contrast, severe climate disasters were shorter-lived and reduced labor productivity by a cumulative 7 percent after three years, mainly through weakened total factor productivity. The COVID-19 pandemic is likely to have a significantly worse impact on productivity than most previous natural disasters due to its global reach and the widespread disruptions to production and transportation, unprecedented measures to control it, and changes to consumer behavior that it has caused. If not properly addressed, the negative effects of adverse disasters on productivity can delay or even derail the convergence of EMDEs to the advanced

economy technology frontier and may undermine hard-won gains in poverty reduction in LICs and FCS countries. Macroeconomic and other policies are important tools to counter the adverse effects of natural disasters, financial crises, and wars. Policies are warranted to reduce the pace of global warming, and to better protect vulnerable areas and populations against natural hazards, as well as to encourage relocation from, and hazard-resistant building in, disaster-prone areas. Enhanced regulatory frameworks can help to reduce the likelihood of financial crises, as well as to mitigate their harm. Appropriate institutional and business climates, including good governance, can also alleviate the initial effects of adverse events, and increase the pace of economic recovery. Fiscal space and transparent governance enable reconstruction efforts, after a natural disaster or armed conflict, to get underway in a timely and effective fashion as well as helping to prevent financial crises. Future research could explore in greater detail the relationship between country characteristics and vulnerability to adverse events. This paper found that countries with rising government debt tend to suffer more from financial crises. A deeper dive could reveal more information about the importance of characteristics such as governance, infrastructure quality, and regulatory quality for mitigating the impact of disasters, and provide insights to build greater resilience to these types of negative shocks.

Annex

A Data, sources and definitions

Identification of natural disasters. The data are taken from the Emergency Disasters Database (EM-DAT) for the period 1960-2018. There are two main categories in the EM-DAT database: i) natural and ii) technological or man-made hazards. Our analysis is solely based on natural disasters. Natural disasters are split into six categories in EM-DAT. Two of these are used as defined in EM-DAT: i) biological (diseases, epidemics); and ii) geophysical (earthquakes, tsunamis, and volcanic activity) disasters. Three are used as one combined climate category in our analysis: i) climatological (extreme heat and cold, droughts); ii) hydrological (floods); and iii) meteorological (cyclones, storms). The sixth category of natural disasters is not included in our analysis due to limited observations: extraterrestrial, defined as hazards caused by asteroids, comets, or meteoroids; or changes in interplanetary conditions that affect the earth's magnetosphere, ionosphere, and thermosphere. The following inclusion criteria are used: i) 10 or more people reported killed; ii) 100 or more people affected, iii) an official declaration of a state of emergency; or iv) a call for international assistance.[40] Seventy percent of natural disasters were climate disasters; whereas biological and geophysical disasters were much less frequent (**Tables A1-A3, Figure 2**). There were 3,897 climate, 1,003 biological, and 830 geophysical disasters over 1960-2018.[41] The results are sensitive to the thresholds on the number of deaths that are applied to identify a natural disaster. For severe natural disasters with a threshold of one death per million inhabitants, the number of natural disasters declines substantially to 1,730, 576, and 256 for climate, biological, and geophysical, respectively.

Comparability of natural disaster databases. Despite substantial improvements in the collection of systematic and harmonized natural disaster data, identifying these events remains challenging. Recorded data differ across different international natural disaster databases due to different methodologies and definitions. The EM-DAT uses a threshold of at least 10 deaths, or 100 people affected, or a declaration of state emergency, or a call for international assistance at the country-level—this definition discards small-scale disasters. By contrast, the DesInventar dataset, maintained by the United Nations Office for Disaster Risk Reduction, uses a lower threshold of at least 1 death or 1 dollar of economic loss, and therefore, has a greater number of recorded events than the EM-DAT (Moriyama et al., 2018). Other databases such as NatCat maintained by Munich Reinsurance Company and Sigma maintained by Swiss Reinsurance Company use different criteria based on the number of deaths or cost of property damages. Comparing the data from EM-DAT, NatCat, and Sigma, only 26 percent of the total events reported during 1985-1999 for four countries (Honduras, India, Mozambique, and Vietnam) were common across the three datasets (Guha-Sapir and Below, 2002). The NatCat and Sigma suggests an increase of natural catastrophes worldwide over the last decade, likely reflecting they are better at capturing less severe events. The NatCat

[40] These selection criteria may, to some extent, bias the estimates towards natural disasters with larger socio-economic impacts. The number of affected people is determined by the sum of injured, homeless, and those who required immediate assistance during the state of emergency.

[41] Felbermayr and Gröschl (2014) show that natural disaster information obtained from the EM-DAT data set suffer from selection bias as the magnitude of destruction depends on GDP per capita, which leads to upwards-biased estimates.

data set finds the number of severe events has been stable for the last decade, suggesting better mitigation policies.

Challenges to the assessment of the economic costs of natural disasters. From an economic perspective, natural disasters are events that cause a shock to the functioning of the economic system, with significant negative impacts on assets, production factors, output, employment and consumption (Hallegatte and Przyluski, 2010). Natural disasters have direct and indirect economic effects. Direct effects include the immediate reduction in output caused by the natural disaster, whereas indirect effects pertain to losses not provoked by the natural disaster itself, but by its consequences. Consider a hurricane or tornado in a country that depends on tourism revenue: besides the direct effects of damage caused by the hurricane, a diminished number of tourists will tend to dampen output growth until reconstruction of facilities is completed and memories of the disaster dissipate.

The literature suggests that the impact of natural disasters on productivity and output tends to be negative.[42] However, it is difficult to compare results across various studies due to different methods and metrics (Felbermayr and Gröschl, 2014; Fomby et al., 2013; Loayza et al., 2012). Cumulative net effects of natural disasters on productivity and output depend on the magnitude and type of natural disaster, and on income level.

- **Magnitude.** Large or multiple natural disasters have sizable negative effects on productivity, both in the short and long-term.[43] On the other hand, the effects of small or moderate natural disasters are ambiguous. In the short-run, the direct effects of these natural disasters include an immediate loss of output (Cavallo et al., 2013; Raddatz, 2007). However, reconstruction activities can subsequently boost growth, innovation, and productivity (Cuaresma et al., 2008; Skidmore and Toya, 2002).

- **Type.** The impacts of natural disasters on output and productivity can vary substantially across types of disasters (Loayza et al., 2012; Hochrainer, 2009). Climate disasters tend to be negative for growth, while other natural disasters have more variable impacts (Felbermayr and Gröschl, 2014).[44] This might reflect the negative disruptive effects of the natural disasters being offset by the positive effects of reconstruction as governments and aid agencies provide investment.

- **Income level.** More generally, advanced economies suffer smaller negative effects on output growth. This could be because they have the resources, human capital, and institutions to mitigate the direct effects of adverse events through reconstruction and investment. In addition, the impacts of natural disasters on productivity and output growth can also vary substantially across economic sectors (Loayza et al., 2012). Given the larger role of agricultural activity in LICs, weather events are likely to have more pernicious effects on productivity

[42] For surveys of the literature see Cavallo and Noy (2011); Kousky (2014). Recent papers include Pigato (2019); Batten (2018).

[43] For example, Cavallo et al. (2010) estimated that the earthquake that hit Haiti on January 12, 2010 caused damage to its economy equivalent to 100 percent of the country's GDP (Cavallo and Noy, 2011; Fomby et al., 2013).

[44] Even within the category of climatic disasters the effects can differ. Fomby et al. (2013); Loayza et al. (2012) find that the effects of droughts are negative. In contrast, Cunado and Ferreira (2014) find that floods can lead to a positive effect in advanced economies, as the additional rainfall could boost crop production in the following years.

than in advanced economies (Acevedo et al., 2018).

Identification of wars. Wars are identified using the World Bank's Correlates of War (COW) database. In this data set, wars are defined as conflicts with at least 1,000 battle-related deaths over the entire episode (Singer and Small, 1994). The COW database covers 1816-2007 and is updated from 2008 to 2018 using the Peace Research Institute Oslo (PRIO) data (Pettersson et al., 2019).[45] Three types of wars are considered in this study: i) intra-state wars, which involve a government in opposition to one or more rebel groups within a state; ii) extra-state wars, which are armed conflicts between a state outside its own territory and a non-state group; iii) inter-state wars, in which both sides are states in the Gleditsch and Ward membership system (Gleditsch et al., 2002). Among the different types of wars, 123 intra-state, 29 extra-state, and 84 inter-state wars are identified for 1960-2018 (**Annex Table A1**). Virtually all intra-state wars take place in EMDEs and 37 percent of intra-state wars happen in LICs.

Identification of financial crises. Data for financial crises are based on the Laeven and Valencia (2018) database for the period 1960-2018.

- **Banking crises** are recorded as having started in a given year if one of the following three conditions are met: i) the share of non-performing loans is above 20 percent of total loans; ii) bank closures reach at least 20 percent of banking system assets; or iii) the costs of restructuring of the banking system exceeds 5 percent of GDP. The sample contains 147 episodes of banking crises for which labor productivity estimates are available. About 23 percent of these episodes occurred in 29 advanced economies; 59 percent in 64 EMDEs excluding LICs; and 18 percent in 21 LICs.
- **Currency crises** are defined to have occurred if the following two conditions are met simultaneously: i) at least a 30-percent depreciation of local currency (from a year earlier), and ii) the magnitude of the depreciation is at least 10 percentage points larger than occurred in the year before. There are 226 currency crises in our sample for which labor productivity estimates are available. Nearly 8 percent of these currency crises occurred in 13 advanced economies; 72 percent in 75 EMDEs excluding LICs; and 20 percent in 23 LICs. About 10 percent of currency crises were accompanied by banking crises.
- **Sovereign debt crises** are defined as the occurrence of a sovereign debt default or restructuring. In the case of a restructuring of public debt without default, the crisis year is the year of restructuring. There are 71 sovereign debt default events in our sample for which labor productivity estimates are available. Fewer than 3 percent of these episodes occurred in two advanced economies; 80 percent in 44 EMDEs excluding LICs; and about 17 percent in 12 LICs (**Tables A1-A3**).
- **A rapid debt accumulation** episode is defined as an expansion from trough to peak of total debt-to-GDP ratios by more than one standard deviation, with troughs and peaks identified using the Harding and Pagan 2002 algorithm. This yields 190 episodes. Almost half of the debt accumulation episodes were associated with financial crises.

[45] To extend the Correlates of War database post-2007, the number of battle-related deaths for each conflict in the PRIO database is aggregated over the whole episode.

Decline in financial crises frequency, rising debt risk. Over the 58-year sample period, currency crises occurred more often than banking and debt crises (**Figure 4**). The frequency of financial crises was three times greater in the 1980s and 1990s than in the post-1990 period. After 2000, there were on average three currency crises, two banking crises and one debt crisis each year. While the frequency of financial crises declined after 2008, concerns have risen about elevated debt and exchange rate pressures in several countries in recent years (Kose et al., 2020). Over the last 30 years, a financial crisis was 50 percent more likely to occur in EMDEs or LICs than in advanced economies (**Figure 4**). The regions most affected by financial crises were SSA and LAC, with ECA experiencing a large increase. Countries in ECA and SSA were markedly more affected by adverse financial events during 2000-18, reflecting their economic links to advanced economies and spillovers from the euro area debt crisis.[46]

B Robustness

Mismeasurement caveats. The literature has identified several issues surrounding the reporting of adverse events. Natural disasters, physical damages and the number of deaths may be under-estimated in areas with limited natural disaster monitoring systems or over-reported to secure foreign aid (Albala-Bertrand, 1993). In addition, there are well-known measurement issues — particularly for LICs — pertaining to the effects of the informal sector (Kousky, 2014), the lack of accounting of reconstruction (Raddatz, 2009), or the effects of insurance (Felbermayr and Gröschl, 2014). However, measurement has been improved by increasingly sophisticated methods for reporting natural disasters, including advanced satellite imagery.

Productivity is prone to measurement issues as well. Any measurement issues in variables used in the estimation of labor productivity (output and employment) and TFP (output, employment, and capital) would be reflected in those productivity measures. It is especially important in countries where services and government sectors account for a large share of the economy due to the difficulties in appropriate measurements of those sectors. Data quality, especially in EMDEs, might include imputed estimations and may be poor beyond the general measurement issues such as the difficulty in taking into account various work-arrangements in measuring labor input. Measurement of capital inputs is complicated due to its large heterogeneity in various aspects such as tangible vs intangible, short lived vs. long-lived assets. The capital input measure used in this study is from PWT 9.1 accounts for different types of assets based on their life span (Inklaar et al., 2019).

Endogeneity and simultaneity between events. An adverse event may be triggered by other negative shocks. This raises endogeneity concerns when estimating the impact of an adverse event on productivity. Natural disasters can fuel political unrest and conflicts, further damaging the productive capabilities of affected countries (Cavallo et al., 2013; Brancati, 2007). Financial crises and adverse external shocks, such as sharp declines in trade or commodity prices, can precipitate conflicts and wars, and lead to severe productivity and output losses (Reynaerts and Vanschoonbeek, 2018). Both wars and natural disasters can lead to rapid debt accumulation, which is often associated with financial crisis (Kose et al., 2020). Among the three types of events explored in this

[46] In the post-crisis period, 2010-18, adverse financial shocks, mainly currency and debt shocks, were more frequent in EMDEs and LICs than in advanced economies.

paper, natural disasters seem the most immune to these endogeneity issues.

Endogeneity with productivity. Natural disasters are in all likelihood not caused by changes in productivity.[47] However, endogeneity concerns may arise in the analysis of financial crises and wars. Subdued productivity growth may contribute to a financial crisis or lead to an armed conflict via feeble output growth. Weakening productivity growth can lead to underperforming loans, as it becomes harder for firms to meet their financial commitments. On a large scale, these underperforming loans can cause substantial deterioration in the balance sheets of financial institutions and trigger financial crises (Kalemli-Ozcan et al., 2018; Aghion et al., 2000). Moreover, low output growth due to weaker productivity growth may lead to lower wealth, increased inequality, heightened social tensions, and polarized communities, and consequently trigger political instability. This reverse causal effect may not be immediate but is likely to materialize only after a few years.

Tables: Descriptive statistics on the frequency of major adverse events

Table A1: Number of episodes

	AEs	EMDEs	LICs	EAP	ECA	LAC	MNA	SAR	SSA	World
Natural disasters	**1031**	**4699**	**1098**	**799**	**481**	**1114**	**313**	**481**	**1510**	**5730**
Climate disaster	843	3054	651	512	355	788	211	300	887	3897
Biological disaster	50	953	369	98	39	124	32	94	566	1003
Geophysical disaster	138	692	78	189	87	202	70	87	57	830
Wars	**45**	**191**	**55**	**37**	**21**	**16**	**35**	**23**	**59**	**236**
Intra war	0	123	46	20	12	11	18	13	49	123
External war	45	68	9	17	9	5	17	10	10	113
Financial Crises	**54**	**390**	**83**	**37**	**57**	**109**	**28**	**10**	**149**	**444**
Banking Crisis	34	113	27	9	22	30	8	4	40	147
Currency Crisis	18	208	44	25	26	52	16	6	83	226
Sovereign Debt Crisis	2	69	12	3	9	27	4	0	26	71

Note: Sample is restricted to the observations where labor productivity growth data exist for the period 1960-2018. The total number of episodes (in bold) for each group of events (all natural disasters, all wars, all financial crises) may include events that occur simultaneously. The events are defined in Annex A. AEs=advanced economies, EMDEs=emerging markets and developing economies (including low income countries), LICs=low income countries.

[47] Even though economic activity is linked to greenhouse gas emissions and climate change, the global spatial and long temporal scale means that productivity has no impact on climate over the timescales considered in this paper.

Table A2: Number of countries experiencing at least one episode

	AEs	EMDEs	LICs	EAP	ECA	LAC	MNA	SAR	SSA	World
Natural disasters	**34**	**137**	**27**	**18**	**21**	**27**	**16**	**8**	**46**	**171**
Climate disaster	33	134	27	18	21	27	15	7	45	167
Biological disaster	20	109	27	15	12	18	10	8	46	129
Geophysical disaster	19	79	15	12	16	18	8	8	17	98
Wars	**13**	**69**	**17**	**9**	**12**	**10**	**13**	**5**	**20**	**82**
Intra war	0	54	15	9	9	8	7	5	16	54
External war	13	37	6	6	6	5	9	3	8	50
Financial Crises	**31**	**133**	**27**	**18**	**21**	**26**	**16**	**7**	**45**	**164**
Banking Crisis	29	85	21	7	17	18	8	4	31	114
Currency Crisis	13	98	23	11	14	20	8	5	40	111
Sovereign Debt Crisis	2	56	12	3	8	18	4	0	23	58

Note: Sample is restricted to the observations where labor productivity growth data exist for the period 1960-2018. The total number of episodes (in bold) for each group of events (all natural disasters, all wars, all financial crises) may include events that occur simultaneously. The events are defined in Annex A. AEs=advanced economies, EMDEs=emerging markets and developing economies (including low income countries), LICs=low income countries.

Table A3: Number of episodes per country

	AEs	EMDEs	LICs	EAP	ECA	LAC	MNA	SAR	SSA	World
Natural disasters	**30**	**34**	**41**	**44**	**23**	**41**	**20**	**60**	**33**	**34**
Climate disaster	26	23	24	28	17	29	14	43	20	23
Biological disaster	3	9	14	7	3	7	3	12	12	8
Geophysical disaster	7	9	5	16	5	11	9	11	3	8
Wars	**3**	**3**	**3**	**4**	**2**	**2**	**3**	**5**	**3**	**3**
Intra war	0	2	3	2	1	1	3	3	3	2
External war	3	2	2	3	2	1	2	3	1	2
Financial Crises	**2**	**3**	**3**	**2**	**3**	**4**	**2**	**1**	**3**	**3**
Banking Crisis	1	1	1	1	1	2	1	1	1	1
Currency Crisis	1	2	2	2	2	3	2	1	2	2
Sovereign Debt Crisis	1	1	1	1	1	2	1	0	1	1

Note: Sample is restricted to the observations where labor productivity growth data exist for the period 1960-2018. The total number of episodes (in bold) for each group of events (all natural disasters, all wars, all financial crises) may include events that occur simultaneously. The events are defined in Annex A. AEs=advanced economies, EMDEs=emerging markets and developing economies (including low income countries), LICs=low income countries.

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