

Disaster Risk and Wealth Inequality

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Abstract

Rich households derive a large part of their income from productive capital, which is at risk of large devaluations in a disaster event. Using data from a survey-based randomized controlled trial (RCT), we first establish that rich households tend to increase their saving rate in response to a higher perceived risk of a disaster, while poorer households show a weakly negative response. Next, we calibrate an incomplete markets model with both idiosyncratic and aggregate (disaster) risk to the survey evidence and use it to quantify the effect of disaster risk on wealth inequality. Regressions on local exposure to natural disasters and on international variation in GDP tail risk support the model prediction that disaster risk increases wealth inequality.

Keywords: Natural disasters, financial crises, geopolitics, GDP tail risk, inequality

JEL-Codes: G51, Q54, E44

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1 Introduction

Disasters and wealth inequality have become increasingly salient over the past two decades. We study whether they are systematically linked. In many countries, the top 10 percent of households hold roughly 60 percent of total wealth, and wealth inequality substantially exceeds income inequality, especially in labor earnings. Explaining the distribution of wealth therefore requires mechanisms beyond heterogeneity in labor productivity. We propose an explanation based on heterogeneous precautionary saving responses to disaster risk. We show, both theoretically and empirically, that when the risk of a severe adverse wealth shock increases, wealthier households raise their saving rates more than poorer households. Within an incomplete markets model that accounts for general equilibrium effects, we find that across many specifications, greater disaster risk raises the concentration of wealth. We therefore establish that the hypothesis of the “great leveler” (Scheidel, 2017; Luetticke et al., 2025), according to which disasters are the main force driving down economic inequality over the centuries, has a flip side: a heightened *risk* of a severe economic downturn—whether driven by natural, geopolitical, or economic disasters—*amplifies* wealth inequality.¹

In the first part of the paper, we investigate the relation between disaster risk perceptions and savings behavior on the household level. For this, we use the results of a randomized controlled trial (RCT) within a representative household survey in Germany, the Bundesbank Online Panel of Households, collected by Beutel and Stockerl (2025) in August 2022. The data not only contains disaster related GDP tail risk expectations of households and employs information treatments within an RCT, but also provides unique granular information on the wealth of households. We provide causal evidence on the heterogeneous relation between tail risk and the savings rate. While high wealth households increase their planned savings rate following an increase in their perceived tail risk, due to the information treatments, low wealth survey participants do not. We find the clearest evidence for heterogeneity for a financial crisis scenario. Quantitatively, when measuring the difference in the active saving rate responses between the Top 20% and the Bottom 80% of the wealth distribution, we find that in response to a 1pp higher tail risk, wealthy households increase their active saving rate by about 10bp more than poorer households.

Next, we develop an incomplete-markets model with uninsurable labor income risk and aggregate disaster risk. We first build intuition using a two-period version of the model. The effect of disaster risk on inequality hinges on heterogeneity in disaster risk exposure, which approximately equals the share of expected asset

¹As in Luetticke et al. (2025), a disaster realization drives down wealth inequality in our model. Since disasters are rare events, however, the effect of risk dominates in the ergodic mean.

income in total income. Poorer households, which rely primarily on labor income, reduce saving in response to higher return risk. In contrast, richer households, whose income derives mainly from returns on financial wealth, increase saving. We show that this pattern arises when households have a sufficiently low elasticity of intertemporal substitution. As a result, heterogeneous precautionary responses to return risk across the wealth distribution cause wealth inequality to rise when return risk increases.

The numerically solved incomplete markets model provides us with a tool to quantitatively analyze how the micro channel—the heterogeneous saving response to aggregate return risk—translates to changes in wealth inequality. We solve both a closed economy and an open economy-version of the model. In the open economy-version, we allow for households to save in a foreign asset without disaster risk, at a lower return that is determined in equilibrium.

In the closed economy, at our main calibration, which matches the survey evidence on saving responses to disaster risk, a one percentage point higher annual disaster probability raises the wealth Gini by 0.22 points and the top 10 percent wealth share by 0.27 percentage points. The effect grows with the concentration of losses: to 0.49 points for macro disasters at the highest concentration we consider, and to 0.28 to 0.70 points for concentrated disasters of the natural-disaster type, which hit few households hard but have a modest aggregate effect.

The open economy with portfolio choice adds two channels that work in opposite directions. First, when disaster risk rises, wealthy households move part of their wealth from domestic capital into the safe asset. They insure through their portfolio rather than through accumulation, and pay for it with a lower return in normal times, so that their wealth grows more slowly; at given prices, this offsets much of the polarization of saving. Second, the portfolio shift moves capital abroad: the domestic capital stock falls, the return on capital rises and the wage falls. This general equilibrium effect redistributes from wage earners to entrepreneurs, who keep their full exposure to the domestic return, and raises inequality by about as much as the portfolio shift lowers it. On balance, a one percentage point higher disaster probability raises the wealth Gini by 0.12 points at the main calibration, about half the effect in the closed economy. For local disasters with a mild aggregate effect, the channels offset each other and the effect is close to zero.

What determines a household’s disaster risk exposure is not only the loss on impact of a disaster, but also the recovery that follows. Following [Bigio and Sannikov \(2021\)](#), we solve the heterogeneous agent model under the assumption that a disaster strikes once and is followed by a deterministic recovery. We solve the deterministic continuation (using a first-order perturbation solution of the model) jointly with the risky steady state, so that the continuation is part of every household’s exposure

to disaster risk. Its shape decides who saves more. When capital is scarce after a disaster, its return rises and the wage falls, which hedges capital owners and exposes workers; the persistent destruction of capital and a fall in profits, both calibrated to the evidence on wars (Luetticke et al., 2025), shift the burden back toward the top. In the open economy, the recovery is governed by our assumption that the fund repatriates foreign assets, the more the scarcer domestic capital is. Repatriation rebuilds the capital stock within five years, whereas in the closed economy it is still 15 percent below its no-disaster path after ten years; the three-year output loss falls from 10.2 to 8.8 percent, and the drop in consumption halves. Open economies, via the optimal portfolio choice of rich households to shift some of their savings into foreign accounts, are thus less exposed to disasters in the aggregate.

In the final empirical part, we assemble observational evidence in order to assess our model predictions. At the macroeconomic level, we combine estimates of country-specific GDP tail risk with data on wealth inequality. We document a strong positive relationship: a 1 percentage point increase in the risk of a severe economic downturn is associated with a 3-4 percentage point increase in the top 10 percent wealth share and the wealth Gini coefficient. Disaster risk remains a statistically significant predictor of wealth inequality after controlling for labor income inequality and other country characteristics, and explains up to 63% of its cross-country variation. The quantitatively larger effect compared to our model may be due to an upward biased estimate, as we do not estimate a causal effect. We also find suggestive evidence that risk of state failure and expropriation lies behind some of the strong positive correlation behind tail risk and wealth inequality, which may imply a higher disaster risk exposure of wealthy households than what our model generates.

In our second empirical exercise with observational data, we look at more local, concentrated disasters, which allows us to regress on (arguably) exogenous variation. In particular, we exploit spatial differences in natural disaster risk across the United States and relate it to local measures of wealth inequality. We find that, at both the state and commuting-zone levels, a one standard deviation increase in exposure to natural disaster risk—plausibly exogenous to local wealth concentration—raises the regional top 10 percent wealth share by 0.5–1 percentage point. Differences in natural disaster risk account for nearly 20 percent of the cross-state variation in wealth inequality in the United States.

The rise in wealth inequality in recent decades has motivated a growing literature to explain this fact. Mian et al. (2020) and Gaillard et al. (2023), among others, argue that the introduction of non-homothetic preferences is needed to explain the “excess” saving of the rich. Moll et al. (2020) and Fernández-Villaverde and Levintal (2024) stress the importance of the “passive” saving of capital gains on the stock

market, in expectation of falling future returns, for explaining recent increases in the top wealth share. [Benhabib et al. \(2015, 2024\)](#) and [Hubmer et al. \(2021\)](#) show that the introduction of idiosyncratic return risk can generate a wealth distribution with a fatter right tail. Our paper adds a new potential channel for explaining higher wealth inequality to this literature. In particular, we show that aggregate risk can cause “active” saving rates to diverge across the wealth distribution.

A recent literature quantifies the consequences of war risk. [Federle et al. \(2024\)](#) document large and persistent output losses of wars, and [Luetticke et al. \(2025\)](#) show in a heterogeneous-agent New Keynesian model that wars level the wealth distribution, through the destruction of capital and higher taxes. [Fried \(2022\)](#) studies natural disasters instead: in her heterogeneous-agent model, storms strike as idiosyncratic shocks to the households they hit. She uses the model to quantify the interaction of adaptation, federal disaster aid and climate change. We allow for both channels in our model: a macro disaster that hits the whole economy and lowers output for years still does not hit households uniformly, but comes with an idiosyncratic component. Varying the degrees of concentration of the disaster and its impact on aggregates allows us to represent different types of disasters. We complement this literature by studying the effect of the risk of a disaster rather than of its realization. Finally, while we treat disaster risk as exogenous, the literature on financial crises and sovereign default explains how disaster risk can increase endogenously. Most related to our paper, [Isojärvi and Jerow \(2026\)](#) connect disasters and inequality in the opposite causal direction: they show that a rising top 1 percent income share shifts bank funding from core deposits toward fragile noncore funding, raising the risk of bank failures.

This paper is also a methodological contribution, as we solve a heterogeneous-agent model with portfolio choice and aggregate disaster risk. We solve for the effect of the risk of a disaster under the assumption, borrowed from [Bigio and Sannikov \(2021\)](#), that households expect the disaster to hit only once and then be followed by a deterministic recovery. This assumption allows for a global solution of the effect of disaster risk. To represent the distribution, we extend our endogenous gridpoint method for distributional dynamics ([Bayer et al., 2026](#)) to portfolio choice, and for the deterministic recovery, we compute the first years after a disaster with our nonlinear update of the distribution ([Bayer et al., 2026](#)). Our method contributes to the literature on solving heterogeneous-agent models with aggregate risk and portfolio choice, which includes [Auclert et al. \(2024\)](#) and [Azinovic and Žemlička \(2024\)](#), who solve an overlapping-generations model with several assets and rare disasters globally, using deep learning.

The rest of the paper is structured as follows. In section 2, we provide causal evidence from an RCT on the heterogeneous impact of disaster risk perceptions on

the saving rate. In section 3, we show in a two-period model, extended by the post-disaster continuation, which households save more and which save less when disaster risk rises. Section 4 presents the quantitative heterogeneous-agent model, calibrated to the micro-level evidence, and section 5 uses it to quantify the link between disaster risk and wealth inequality for different types of disasters and in different model settings. In section 6, we compare the model’s predictions with the relation between disaster risk and wealth inequality across U.S. regions and across countries. Section 7 concludes.

2 Survey evidence: disaster risk and saving rates across the wealth distribution

In this section, we provide causal micro-level evidence on the heterogeneous role of disaster risk for the savings behavior of households. To do so, we exploit data from an existing randomized information experiment embedded in the Bundesbank Online Panel of Households (BOP-HH), Wave 32 (August 2022) (Beutel and Stockerl, 2025). The survey covers a nationally representative sample ($N = 8996$) of German households and allows us to study how exogenous variation in perceived disaster risk affects planned saving behavior across the wealth distribution.

2.1 Data

Respondents were randomly assigned to receive qualitative information about one of four disaster scenarios: (i) a financial crisis, (ii) a new pandemic, (iii) a war between China and Taiwan, and (iv) an energy supply crisis. For each disaster type, participants received either a positive information treatment (suggesting resilience and limited economic damage) or a negative information treatment (emphasizing vulnerabilities and potentially severe consequences). A control group received no information. Appendix B lists the relevant survey questions for our analysis as well as the exact treatment texts provided to respondents, while Bundesbank (2025) gives an overview over the BOP-HH survey in general and the full questionnaire of the respective survey wave.

After the treatment, respondents reported their planned average monthly expenditures over the next twelve months in four categories: major purchases, housing, other living expenses, and savings. We define the *active saving rate* as planned monthly savings divided by monthly net household income, which respondents report in 13 brackets; we use the bracket midpoints. Net household income includes labor income, pensions, transfers, rental and other income, after taxes and social security contributions. We report effects on the saving rate in percentage points. This

measure captures adjustments in active portfolio accumulation rather than passive wealth changes. Planned saving cannot be negative in the survey, and 23 percent of respondents plan to save nothing.

Respondents also report their perceived probability that the disaster occurs and the drop in German GDP they would expect if it did, once before the information treatment (over a horizon of three years) and once after it (over a horizon of two years). We convert the probabilities to annual probabilities, $p_i = 1 - (1 - P_i)^{1/h}$ with $h = 3$ before and $h = 2$ after the treatment, and define the perceived *expected annual loss* as $\Phi_i = p_i \times L_i$, where L_i is the perceived GDP loss. Φ_i is measured in percentage points of GDP.

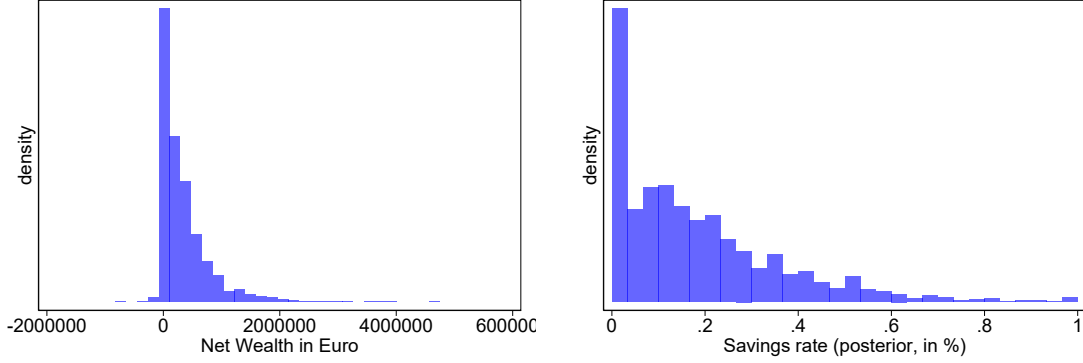
We split the sample along the net wealth distribution and define high-wealth households as those in the top 20 percent. In the survey, the median net wealth amounts to approximately €74,000 in the bottom 80 percent and €855,000 in the top 20 percent. We use a 20% cutoff for high wealth individuals to strike a balance between capturing the top of the wealth distribution while still being able to maintain a sufficient statistical power in the sample, given a limited overall sample size.

All estimates use the survey weights, which ensure the representativeness of the sample relative to the German population. Because the saving rate is bounded, skewed and has a mass point at zero (see the right panel of Figure 1), we limit the influence of outliers by robust regression: we first estimate a robust (Huber and biweight) regression of the saving rate on the treatment and control variables and then use the resulting robustness weights, multiplied by the survey weights, in a weighted least squares regression. Our baseline sample contains all respondents with a valid saving rate and wealth information, about 1,500 per disaster type.

We check several alternatives to this baseline. First, we drop respondents for whom “major purchases” make up more than 40% of planned outlays, as large planned purchases, such as a new car or house, can heavily distort the saving rate.² Second, we drop respondents who did not finish the survey in one sitting but at a later point in time, as taking a pause may affect the effect of the information treatment. Third, we multiply the survey weights by inverse probability weights, to adjust for any selection effect into the high or low wealth groups (see, e.g., [Piccolo and Gorodnichenko, 2025](#)). These weights are calculated from propensity scores estimated by a probit model of a high-wealth dummy on age, gender and education. Section 2.3 reports the results, together with estimates without the robust regression, with the top 1 percent of saving rates trimmed, and for saving over planned outlays.

²This is relevant for 6.0% of survey respondents in our sample.

Figure 1: Survey Data - Description



Notes: Left panel: distribution of total wealth in the survey. Right panel: distribution of saving rates (planned saving over planned outlays) in the survey.

2.2 Empirical Specification

To isolate heterogeneous treatment effects, we estimate the impact of negative information relative to positive information for each disaster type separately. The positive treatment serves as an *active control group*, allowing us to identify how more adverse information shifts saving behavior relative to more reassuring news about the same disaster.

Specifically, we estimate:

$$s_i^{post} = \alpha_0 + \beta_1 \mathbb{I}_i(\text{Negative}) + \beta_2 [\mathbb{I}_i(\text{Negative}) \times R_i] + \beta_3 R_i + \gamma' D_i + \varepsilon_i, \quad (1)$$

where s_i^{post} denotes the planned saving rate, R_i indicates whether the respondent belongs to the top 20 percent of the wealth distribution, and D_i is a vector of controls (age group, gender, education and income quintile).

The coefficient β_1 captures the treatment effect for lower-wealth households (bottom 80 percent), $\beta_1 + \beta_2$ the effect for the top 20 percent, and β_2 the differential response of high-wealth households relative to the bottom 80 percent.

Scaling to the model experiment. The coefficients in (1) measure the effect of reading the negative treatment-text rather than the positive treatment-text. This effect has no natural unit, because the texts differ in how much they move beliefs. Foreshadowing our model experiment, we aim to translate this to the effect of raising the annual disaster probability by one percentage point, with a disaster that destroys 10 percent of output. To map the survey into this experiment, we measure how much the treatment moves beliefs and express the saving response per unit of that belief shift. For this, we estimate a second regression, the *first stage*, with the same right-hand side, sample and survey weights as equation (1), estimated by weighted least

squares without the robust regression step, but with the post-treatment expected annual loss Φ_i^{post} as the dependent variable:

$$\Phi_i^{post} = \delta_0 + \delta_1 \mathbb{I}_i(\text{Negative}) + \delta_2 [\mathbb{I}_i(\text{Negative}) \times R_i] + \delta_3 R_i + \kappa' D_i + u_i. \quad (2)$$

The coefficient δ_1 is the shift in expected loss caused by the negative text in the bottom 80 percent, and $\delta_1 + \delta_2$ the shift in the top 20 percent.

We impose the restriction that the first stage is common across wealth groups; scaling each group by its own shift would leave the response of the top 20 percent unidentified. For this, we compute the average shift across both groups,

$$\Delta\Phi = (1 - \omega_R) \delta_1 + \omega_R (\delta_1 + \delta_2) = \delta_1 + \omega_R \delta_2, \quad (3)$$

where ω_R is the survey-weighted share of top 20 percent respondents in the sample.³ Dividing a saving response from equation (1) by $\Delta\Phi$ gives the saving response per percentage point of expected annual loss. This ratio is a Wald-type (indirect least squares) estimate of the effect of Φ_i on the saving rate, with the treatment as the instrument and a first stage restricted to be common across wealth groups. Its interpretation assumes that the treatments affect saving only through the perceived expected loss.⁴

A one percentage point higher annual probability of a 10 percent output loss raises the expected annual output loss by 0.1 percentage points. The response per percentage point of disaster probability is therefore

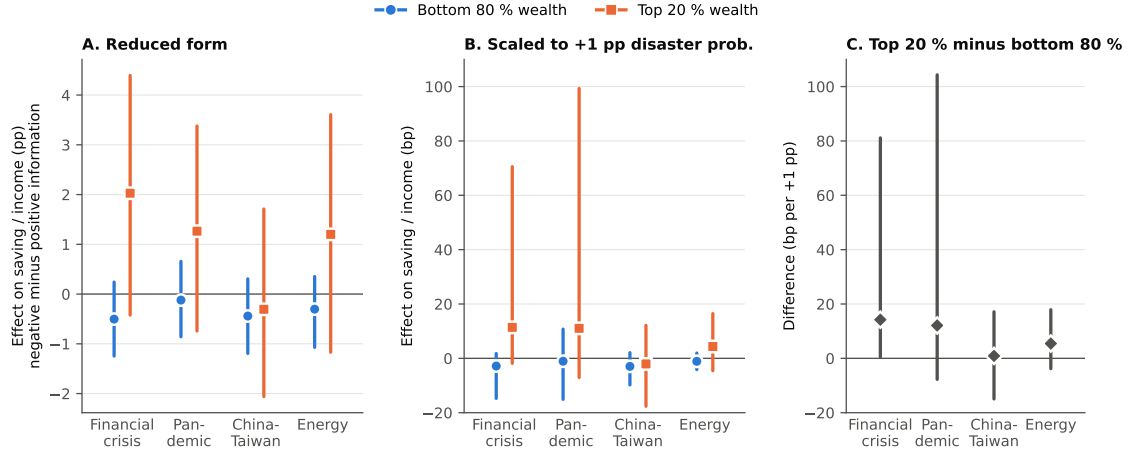
$$\tilde{\beta} = 0.1 \times \frac{\beta}{\Delta\Phi}, \quad \beta \in \{\beta_1, \beta_1 + \beta_2, \beta_2\}, \quad (4)$$

for the bottom 80 percent, the top 20 percent and their difference, respectively. Because both groups are divided by the same $\Delta\Phi$, the scaled difference equals the difference of the scaled group responses. We scale by the expected loss rather than by the probability alone because the treatments move the perceived size of the disaster as well as its probability. For high-wealth households in the financial crisis experiment, the negative text raises the perceived GDP loss by 5.8 percentage points, but the perceived annual probability by only 3.6 percentage points, which is not significant. Scaling by the probability alone would attribute the whole saving response to a small shift in probability.

³A common shift is not rejected in the financial crisis, pandemic and China–Taiwan war experiments, but it is in the energy crisis experiment, where the shift is concentrated in the bottom 80 percent (3.2 percentage points, against 0.2 in the top 20 percent; the difference has a standard error of 1.4). There, the common first stage restriction binds.

⁴It is not a two-stage least squares estimate, since the reduced form (1) is estimated by robust regression.

Figure 2: RCT - Results



Notes: Panel A: effect of the negative relative to the positive information treatment on the planned saving rate (planned saving over net household income), in percentage points, for the bottom 80 percent and the top 20 percent of the wealth distribution (Equation 1). Panel B: the same effects per percentage point of annual disaster probability, in basis points, obtained as $0.1 \times \beta / \Delta\Phi$, where $\Delta\Phi$ is the treatment effect on the perceived expected annual GDP loss (Equation 4). Panel C: difference between the top 20 percent and the bottom 80 percent on the scale of panel B. Bars show 90 percent confidence intervals: bootstrap percentile intervals in panel A, Anderson–Rubin-type sets in panels B and C (999 bootstrap draws).

We compute confidence intervals by a bootstrap with 999 draws that resamples respondents within treatment arms and repeats the robust regression in each draw. For the scaled effects in (4), we report Anderson–Rubin-type confidence sets, which invert the bootstrap test of $\beta - \tilde{\beta} \Delta\Phi / 0.1 = 0$ and remain valid when the first stage is weak.

2.3 Results

Figure 2 summarizes the heterogeneous treatment effects. In the financial crisis experiment, we observe a pattern consistent with our model: high-wealth households increase their saving rate in response to the negative treatment, whereas lower-wealth households exhibit a weakly negative response (panel A). The saving rate of the top 20 percent rises by 2.5 percentage points more than that of the bottom 80 percent. The pandemic and energy crisis experiments show the same pattern with smaller differences of 1.4 percentage points and 1.5 percentage points, which are not significant. The China–Taiwan war experiment shows no heterogeneous effect.

Panels B and C express the response in terms of the probability of a severe output drop—a disaster. Per percentage point of annual disaster probability, the top 20 percent raise their saving rate by 14 basis points more than the bottom 80 percent in the financial crisis experiment (significantly different from zero at 5%,

one-sided test), by 12 basis points in the pandemic experiment, by 5 basis points in the energy crisis experiment, and by 1 basis point in the China–Taiwan war experiment (not significant). Pooled over the four disaster types, the saving rate-response of wealthy households is 7.4 basis points higher (significant at 5%). The response of the bottom 80 percent is small and not significantly different from zero in all experiments. The scaled effects are very imprecise, as the treatments shift the perceived expected loss by only 1.1 to 2.8 percentage points.

Robustness. Table A1 in Appendix A shows how the scaled differences in panel C of Figure 2 change under alternative samples, weights and treatments of outliers. In each specification, we re-estimate both the saving regression (1) and the first stage (2) on the same sample and with the same weights. The first row reproduces panel C.

The pooled estimate is stable. It lies between 7.4 and 9.3 basis points in all specifications except one, and it is significantly positive at the 5 percent level in a one-sided test in all specifications that use the robust regression, except one. The exception is the use of inverse probability weights on the full sample, which lowers the pooled estimate to 3.9 basis points because the China–Taiwan war estimate turns negative. Without the robust regression, the pooled point estimate is similar (7.7 basis points), but a small number of extreme saving rates makes the confidence set too wide to be informative.

Among the single experiments, the financial crisis estimate is positive and large in all specifications, between 13 and 22 basis points. It is significant at the 5 percent level with the baseline sample, with inverse probability weights and with trimmed saving rates, and at the 10 percent level when respondents with large planned purchases or interrupted interviews are dropped; it is not significant in the remaining two specifications. Dropping interrupted interviews weakens the first stage of this experiment, so that its confidence set becomes unbounded. The pandemic and energy crisis estimates remain positive, between 2 and 12 basis points, in all specifications with the robust regression, and are significant at the 10 percent level in one specification each. The China–Taiwan war estimate ranges from -6 to 8 basis points in the specifications with the robust regression and is never significant.

3 Analytical model

This section explains why disaster risk raises the saving rates of wealthier households, while poorer households show a null or slightly negative response. We find that the idiosyncratic exposure of a household to the destruction of capital, compared with a common threshold set by the elasticity of intertemporal substitution, determines

the saving rate response to disaster risk. We first derive the threshold in a two-period problem, and then extend the analysis for the effect of the continuation after a realized disaster on the household's exposure. Derivations are in Appendix D.

3.1 A two-period model

Consider the following two-period consumption-savings choice problem. A household with wealth a can save in one asset with ex-post gross return R , and receives predetermined labor income y .⁵ The household has period-utility u , time-preference β , and chooses the level of saving k s.t.

$$u(a - k) + \beta \mathbb{E}[u(Rk + y)] \quad (5)$$

is maximized. For financially unconstrained households, the optimal savings choice is characterized by the first-order condition

$$-u'(a - k) + \beta \mathbb{E}[Ru'(Rk + y)] = 0 \quad (6)$$

The disaster experiment. Suppose that the only risk is a disaster: with probability q , a fraction D of the household's saved capital is destroyed. The expectation in (6) becomes

$$\mathbb{E}[Ru'(c_1)] = (1 - q) R_0 u'(c_N) + q (R_0 - D) u'(c_D), \quad (7)$$

with consumption $c_N = \bar{c} := R_0 k + y$ without and $c_D = \bar{c} - Dk$ with a disaster. Raising q at a given saving choice k shifts weight between these two outcomes,

$$\left. \frac{\partial}{\partial q} \mathbb{E}[Ru'(c_1)] \right|_{q=0} = R_0 [u'(c_D) - u'(c_N)] - D u'(c_D). \quad (8)$$

The two terms represent substitution and income effects. The second is the *expected-return* effect: per unit of saving, the disaster lowers the expected payout by D , which makes saving less attractive. The first is the *precautionary* effect: the disaster lowers consumption, which raises marginal utility in the disaster state; by how much depends on how exposed the household's consumption is to the destruction. We

⁵We abstract from idiosyncratic labor income risk in this section; in the full model in section 4, we model uninsurable labor productivity risk. In standard calibrations, the persistence of labor productivity is quite high, so that the analysis here can be seen as a close approximation to the more complex model.

measure that exposure by

$$\lambda := -R_0 \left. \frac{\partial \log c_D}{\partial D} \right|_{D=0} = \frac{R_0 \psi}{\bar{c}}, \quad \psi := - \left. \frac{\partial c_D}{\partial D} \right|_{D=0} \quad (9)$$

Exposure λ rises with the expected gross return R_0 and the semi-elasticity of consumption with respect to the destroyed share of capital. In the two-period problem the household consumes what it saved, so the exposure is the entire principal, $\psi = k$, and λ has a particularly easy expression: it equals the share of gross asset income in total income,

$$\lambda = s := \frac{R_0 k}{R_0 k + y}. \quad (10)$$

Labor income is the key to heterogeneity: a household that lives mostly off its labor income has a low λ , a household that lives off its wealth a high one.

Proposition 1 (Disaster threshold). *Suppose the household has CRRA preferences with γ the parameter of relative risk aversion, and chooses an interior optimum. For a sufficiently small destruction D , the leading-order response of its saving rate to an increase in disaster probability has the sign of $\gamma\lambda - 1$. Thus, away from the knife-edge $\lambda = 1/\gamma$, the household raises its saving rate if and only if*

$$\lambda > \frac{1}{\gamma}. \quad (11)$$

See Appendix D for the proof. Intuitively, a higher disaster probability lowers the expected return by D per unit of saving, which by itself lowers saving with a strength governed by the elasticity of intertemporal substitution $1/\gamma$. D also raises the expected marginal utility of saving by $\gamma\lambda D$, the household's exposure scaled by its risk aversion. Households whose exposure exceeds $1/\gamma$ save more, the others save less. Since λ rises with the share of income that comes from wealth, higher disaster risk raises the saving rates of the wealthy and lowers those of households who depend on labor income, which widens wealth inequality.

Accounting for the possibility of $\lambda < 1$ extends the simplified treatment of optimal portfolio choice when financial and human wealth is not distinguished (e.g. Barro (2006)). In fact, this distinction is the focus of the analysis in Angeletos (2007), which is closely related to the mechanism we analyze here: he finds that when the average share of risky over total wealth is less than one, higher investment risk can lead to less saving in the aggregate. The condition on the share of risky wealth (here, λ) and preferences, under which this result holds (see Proposition 3(ii) in Angeletos (2007)), is exactly the one that obtains when we fix the mean and analyze second order effects (see Appendix D): $\rho\lambda < 2$, where $\rho = 1 + \gamma$ is

the household's coefficient of relative prudence under CRRA preferences. Going up to third order, we find that the corresponding cutoffs are set by relative prudence and temperance, and the response is again determined by λ . We contribute to the literature by applying these results to the analysis of heterogeneous saving rates, which are a function of idiosyncratic risk exposure λ_i .

3.2 The continuation after a disaster

In the two-period problem, only capital owners lose from a disaster: the wage of the disaster period is paid from production with the full capital stock. A destruction of capital is long-lasting, however (Nakamura et al., 2013). A neoclassical production function predicts that, while the capital stock is rebuilt, labor is paid less and capital earns more, as capital is scarce. Analyzing this basic setting, we find that accounting for the continuation after a disaster mitigates the relative exposure to a disaster.

As a first pass (before going to the numerical model), we capture this with two persistences. A fraction $\phi \in [0, 1)$ of the aggregate capital shortfall, and with it of the wage loss, remains from one period to the next, so that t periods after the disaster the shortfall is ϕ^t times its initial size: at $\phi = 0$ the capital stock is restored at once, and as ϕ approaches one the shortfall becomes permanent. In the meantime capital earns a higher post-disaster return $R_d > R_0$. Likewise, a fraction $\chi \in [0, 1]$ of the household's own capital loss remains from one period to the next, so $k_t = (1 - D\chi^t)k$: at $\chi = 0$ the household's capital is restored after one period, while at $\chi = 1$ its loss is permanent. ϕ governs the economy's recovery, χ the household's own.

As we show in Appendix D, with a long horizon, the relevant consumption level is annuitised lifetime income, $\bar{c} = W + (R_0 - 1)k$, and it falls with the destruction by the elasticity $\psi = \psi^N + \psi^K$, where

$$\psi^N = \frac{\alpha\phi W(R_d - 1)}{R_d(R_d - \phi)}, \quad \psi^K = (R_d - 1)v k, \quad v := \frac{R_d - 1}{R_d - \chi} \leq 1. \quad (12)$$

The wage component ψ^N is a new, human-wealth exposure. The asset component ψ^K is scaled by the hedge factor v : the higher post-disaster return partly offsets the loss while wealth is rebuilt. With $\tilde{s} := (R_0 - 1)k/\bar{c}$ being the share of asset income in total income flows (in analogy to s in the two-period model), the exposure (9) becomes

$$\lambda = \frac{R_0\psi}{\bar{c}} = \underbrace{v\tilde{s}}_{\text{exposed asset income}} + \underbrace{\frac{R_0\psi^N}{\bar{c}}}_{\text{exposed labor income}}, \quad (13)$$

and the threshold of Proposition 1 applies unchanged to this exposure. The horizon changes exposures, not the threshold.

The recovery compresses exposures across the distribution. The wage channel gives every household, including those without wealth, a floor of exposure, while the scarcity return hedges capital owners and flattens the slope in $\tilde{s}$. We can illustrate the mechanism by referring to an the extreme case of an *open economy* with elastic international capital supply. In that scenario, foreign capital restores the capital stock at once ($\phi = 0$) and prices do not move, while the household's loss is permanent ($\chi = 1$): exposure equals $\lambda = \tilde{s}$, which rises steeply with wealth (as in the two-period model). In a *closed economy*, the scarcity of capital hedges the rich and the wage loss exposes the poor, which can potentially lift every household above the threshold of Proposition 1.

Proposition 2 (The continuation and the threshold). *Fix the wage persistence $\phi < 1$, and let $\lambda(\chi)$ denote the exposure in (13) as a function of individual persistence $\chi \in [0, 1]$. Then $\lambda(\chi)$ is increasing in χ , and:*

- (i) *if $\lambda(1) < 1/\gamma$ for every household, no household raises its saving rate in response to higher disaster risk at any χ ;*
- (ii) *otherwise, there is a critical persistence χ^* such that, for $\chi > \chi^*$, the most exposed households cross $1/\gamma$ and raise saving, while the remainder lower it;*
- (iii) *χ^* is decreasing in γ , since the threshold $1/\gamma$ is.*

The proposition says that the split of saving responses by wealth requires that capital owners bear a persistent part of the disaster's losses themselves.

Disasters that also lower productivity. The literature typically models macroeconomic disasters as a simultaneous capital destruction and negative productivity shock (Barro, 2006; Gourio, 2012; Nakamura et al., 2013). If the productivity loss starts after the disaster period, it changes the household's response only through the exposure λ , and the threshold $1/\gamma$ is unchanged. Productivity affects households through two channels with different incidence. A permanent loss lowers the level of the economy and with it every household's income, much like a wage loss, which raises the exposure of the poor most. A loss that makes capital abundant relative to productivity for a while lowers the return to capital, which raises the exposure of the rich and steepens exposure across the distribution. In the limit in which productivity falls permanently and in proportion to the capital loss, prices never move, every household loses the same fraction of income, $\lambda \approx 1$ for all, and the condition $\gamma\lambda > 1$ becomes $\gamma > 1$: the representative-agent result of Gourio (2012) that disaster risk raises saving if and only if the elasticity of intertemporal substitution is below one. Appendix D.5 derives the exposure under productivity losses and the range of loss sizes for which disaster risk splits the distribution.

From the analytical model to the quantitative model. The analytical model highlights three objects that are crucial for the understanding of the quantitative model of Section 4. First, the elasticity of intertemporal substitution $1/\gamma$ has to be low enough in order to match the survey evidence that wealthy households increase their saving in response to higher disaster risk. Second, risk exposure λ_i governs the heterogeneity in saving rates responses, and rises with the share of income from wealth. In the quantitative part, we also solve a variant of the model with portfolio choice between risky and save assets, which will allow households to choose their risk exposure optimally (at the cost of a risk premium). Third, the continuation after a disaster—how fast capital is rebuilt, how prices and profits move, whether productivity falls—shifts exposures across the distribution, so that the same disaster probability can raise saving at the top and lower it at the bottom, or raise it everywhere. The quantitative model computes these exposures from the full post-disaster recovery path rather than from the annuity approximation used above.

4 A heterogeneous-agent model with disaster risk

This section presents the quantitative model. It is an incomplete-markets economy with uninsurable labor income risk, entrepreneurs who earn profits, and aggregate disaster risk. We first describe the closed economy with a single asset, then the open economy, in which households can shield part of their wealth from disasters by holding a safe foreign asset. The disaster can be concentrated on few households, as natural disasters are, or hit the whole economy, as wars and financial crises tend to do. Section 5 reports the results.

4.1 Households

There is a continuum of households of mass one. Household i supplies one unit of labor inelastically and has idiosyncratic labor productivity h_{it} , which follows a log AR(1) process,

$$\log h_{it+1} = \rho_h \log h_{it} + \epsilon_{it+1}, \quad \epsilon_{it+1} \sim \mathcal{N}(0, \sigma_h^2). \quad (14)$$

In addition, households switch between being workers and being entrepreneurs. A worker becomes an entrepreneur with probability ζ per quarter, and an entrepreneur returns to being a worker with probability ι . Entrepreneurs receive the economy's profits, $\Pi_t = \mu_{Y,t} Y_t$, in equal shares, and supply labor of productivity h_E .⁶ House-

⁶The structure follows the worker–entrepreneur setup of Bayer et al. (2024). Entrepreneurial spells are long: with $\iota = 0.0063$ an entrepreneur keeps the status for about 40 years on average. Profits are a large, transitory income, which generates a strong precautionary motive for

holds have CRRA preferences with relative risk aversion γ and discount factor β , and cannot borrow.

In the one-asset economy, households save in claims on domestic capital, $m_{it} \geq 0$. In a quarter without a disaster, the budget constraint is

$$c_{it} + m_{it+1} = R_t m_{it} + w_t h_{it} + \mathbf{1}_{\{i \in E\}} \Pi_t / \varsigma_E, \quad (15)$$

where $R_t = 1 + r_t$ is the gross return on capital, w_t the wage and $\varsigma_E = \zeta / (\zeta + \iota)$ the mass of entrepreneurs.

4.2 Production and prices

A representative firm produces $Y_t = Z_t K_t^\alpha N^{1-\alpha}$ with aggregate labor N . Firms have market power, and a share $\mu_{Y,t}$ of output is paid out as profits. Factor prices are therefore $(1 - \mu_{Y,t})$ times the marginal products,

$$r_t = (1 - \mu_{Y,t}) \alpha Z_t K_t^{\alpha-1} N^{1-\alpha} - \delta_t, \quad w_t = (1 - \mu_{Y,t})(1 - \alpha) Z_t K_t^\alpha N^{-\alpha}. \quad (16)$$

In normal times $Z_t = 1$, $\delta_t = \delta_0$ and $\mu_{Y,t} = \mu_Y$.

4.3 Disasters

A disaster strikes with probability p per year ($p/4$ per quarter). It has four components, which we calibrate to the evidence on wars and macroeconomic disasters (Table 1).

1. *Capital destruction on impact.* In the disaster quarter, a fraction D of the capital stock is destroyed. The destruction can be spread evenly or concentrated: a fraction $\pi_{\text{hit}} = D/d$ of households is hit and loses a share d of its wealth, while the others lose nothing. Raising the loss-given-hit d at constant D is a mean-preserving spread of the destruction. The uniform disaster is $d = D$.
2. *Persistent destruction.* After the disaster quarter, depreciation stays elevated and returns to δ_0 at the rate ρ_δ per quarter. This adds destruction in the quarters after impact and keeps the return on capital low while capital is rebuilt (Luetticke et al., 2025).
3. *Productivity loss.* TFP falls by D_Z on impact and recovers at the rate ρ_Z , as in the macro-disaster literature (Gourio, 2012; Nakamura et al., 2013).
4. *Profit squeeze.* The profit share falls to $(1-\psi)\mu_Y$ on impact and recovers in logs at the rate ρ_μ . Profits fall after wars, persistently (Luetticke et al., 2025); with

entrepreneurs. Consequently, entrepreneurs end up at the top of the wealth distribution.

lower profits, factor prices rise relative to marginal products, so the squeeze shifts the post-disaster burden from workers and savers to entrepreneurs.⁷

We distinguish two regimes. A *local* (natural-disaster type) disaster is concentrated (d large), destroys capital on impact only and leaves productivity unchanged; it lowers GDP by less than 2 percent. A *macro* disaster combines destruction, its persistent tail, the productivity loss and the profit squeeze, and lowers annual GDP by about 10 percent over three years, the size of output losses in wars (Federle et al., 2024) and consumption disasters (Nakamura et al., 2013).

4.4 The risky steady state and the post-disaster continuation

We study the economy in its risky steady state (Coeurdacier et al., 2011): the stationary distribution of wealth and income that obtains when households anticipate disasters but none occurs. Wealth inequality and its response to the disaster probability are therefore driven entirely by the households' ex-ante saving and portfolio decisions, not by realized losses; we study realized disasters separately in Section 5.

What households anticipate is the post-disaster continuation. Following Bigio and Sannikov (2021), we do not model a recurrent disaster state. Instead, if a disaster strikes, the economy is hit once and then follows a deterministic recovery path to a different, deterministic steady state. With V_m the marginal value of wealth in normal times and V_m^D its counterpart when a disaster strikes, the Euler equation of an unconstrained household is

$$u'(c_{it}) = \beta \mathbb{E}_t \left[\left(1 - \frac{p}{4}\right) R_{t+1} u'(c_{it+1}) + \frac{p}{4} V_m^D(m_{it+1}, h_{it+1}) \right], \quad (17)$$

where

$$V_m^D(m, h) = \pi_{\text{hit}}(R^D - d)u'(c_{\text{hit}}^D(m, h)) + (1 - \pi_{\text{hit}})R^D u'(c_{\text{not hit}}^D(m, h)) \quad (18)$$

is the marginal value of a unit of wealth carried into the disaster quarter, R^D the gross return in that quarter before the household-specific loss, and c^D consumption in the disaster quarter, chosen optimally given the recovery path that follows. The continuation depends on the distribution of wealth on which the disaster strikes, so it is solved jointly with the risky steady state: a fixed point between the stationary distribution, which depends on V_m^D through (17), and V_m^D , which depends on the distribution through the recovery path. The disaster quarter and the first quarters of the recovery are solved exactly and nonlinearly, after which the distribution is

⁷For tractability, we choose to force the profit share exogenously. Procyclical profits arise endogenously in models with wage stickiness, for example.

“handed over” to the first-order solution of the deterministic economy. Appendix C.2 describes the algorithm, including the Nonlinear DEGM Update (NDU) of Bayer et al. (2026), on which this method builds.

This construction captures what the analytical model of Section 3 identifies as decisive: the continuation after a disaster is part of each household’s risk exposure. In the closed economy capital becomes scarce after a disaster, so its return rises and the wage falls, which hedges capital owners and exposes workers; the persistent destruction and the profit squeeze work in the opposite direction, toward the top.

4.5 Openness: portfolio choice and a safe asset

In the open-economy version, households split their wealth between direct holdings of domestic capital and a fund that holds a foreign asset with a safe return R^* .⁸ Disaster risk therefore has a second margin besides the saving rate: households can shield part of their wealth by moving it into the fund, at the cost of a lower return in normal times.

Households’ portfolio choice. A worker chooses the share $\theta_{it} \in [0, 1]$ of her saving m_{it+1} that she holds as direct capital. In a normal quarter direct capital pays R_{t+1} ; in a disaster quarter it pays $R_{t+1}^D - \ell_{it+1}$, with $\ell_{it+1} = d$ for households that are hit and 0 otherwise. Her portfolio return is

$$R_{it+1}^P = \theta_{it} R_{it+1}^L + (1 - \theta_{it}) R^*, \quad (19)$$

with R_{it+1}^L the return on direct capital. With the household’s stochastic discount factor

$$M_{it+1} = \beta \frac{u'(c_{it+1})}{u'(c_{it})}, \quad (20)$$

where c_{it+1} is consumption in the disaster quarter if a disaster strikes, the saving decision satisfies the Euler equation (17) with the portfolio return R_{it+1}^P , and the share satisfies

$$\mathbb{E}_t [M_{it+1} (R_{it+1}^L - R^*)] \begin{cases} \geq 0 & \text{if } \theta_{it} = 1, \\ = 0 & \text{if } 0 < \theta_{it} < 1, \\ \leq 0 & \text{if } \theta_{it} = 0. \end{cases} \quad (21)$$

⁸In a richer version, the fund can also hold safe claims on domestic capital that entrepreneurs operate on top of their own equity, which absorbs the first loss, in exchange for a premium that entrepreneurs price with their own stochastic discount factor. At all our calibrations the fund holds only foreign assets. The reason is that, as an entrepreneur’s equity and her guarantee are lost in the same disaster-event that hits her firm, her price for the guarantee (4.1 percent per year at the main calibration) exceeds the return on capital net of R^* . When we allow entrepreneurs to diversify into the fund (which we generally rule out, see below), they are able to price the guarantee lower and the fund keeps a small domestic leg, 1 to 10 percent of its assets (see Section 5).

The expectation runs over the household's next-quarter labor productivity, whether a disaster strikes, and whether the household is hit. Since direct capital carries the concentrated loss d and the foreign asset does not, the excess return of direct capital has to compensate for the household's own disaster risk. Households whose consumption depends more on their wealth, and is thus more exposed to the loss, require more compensation. We solve for θ_{it} on a grid of portfolio shares.

Entrepreneurs do not diversify. Entrepreneurs hold all of their wealth as equity in their own firm and cannot hold the fund, so they carry the losses of their own firms unhedged. This restriction stands in for the financial frictions that make entrepreneurs hold most of their wealth in their own business, at returns that do not compensate them for the lack of diversification (Moskowitz and Vissing-Jørgensen, 2002; Cagetti and De Nardi, 2006). This assumption is crucial for models with portfolio choice to generate a rise in wealth inequality from higher disaster risk; Section 5 reports what happens when entrepreneurs can diversify into the fund and choose θ_{it} like the other households.

Repatriation of foreign assets. After a disaster, the fund repatriates part of its foreign position into domestic capital, which rebuilds the capital stock faster than in the closed economy. Along the recovery path the foreign position F_t follows the reduced-form rule

$$F_{t+1} = F_t - \eta_F (r_{t+1} - r_{SS}) W_t, \quad (22)$$

where W_t is aggregate household wealth, r_{t+1} the return on domestic capital, and r_{SS} the return on capital in the deterministic steady state to which the economy converges after a disaster. When capital is scarce and its return is high, the fund moves wealth home in proportion to the return premium. The premium is measured relative to r_{SS} , so the position is constant in the deterministic steady state, although r_{SS} exceeds R^* there. The rule has no target for the foreign position itself, but the position is anchored through the return: a larger foreign position leaves less domestic capital, which raises its return and brings wealth home. In the long run, the return pins down the domestic capital stock and households' saving pins down their wealth, so the position returns to $f_{SS}W$, with f_{SS} the foreign share of wealth in the deterministic steady state.⁹ The rule is not derived from the households' portfolio choice: it stands in for international capital flows after a disaster.

⁹In fact, f_{SS} is also the foreign share in the risky steady state. Without disaster risk, direct capital and the foreign asset are both safe, and households would hold only the one with the higher return. The deterministic steady state therefore takes the composition of wealth from the risky steady state, $f_{SS} = F_{RSS}/W_{RSS}$. Since the continuation depends on the deterministic steady state, and the risky steady state on the continuation, f_{SS} is part of the fixed point between the risky steady state and the continuation (section 4.4). Each disaster probability therefore has its own deterministic steady state.

4.6 Calibration

A model period is a quarter. Table 1 summarizes the calibration. Technology and the income process are standard. The entrepreneur mass is 1 percent, and the exit rate implies long entrepreneurial spells; together with the profit share, this generates a wealth Gini of about 0.75 in the risky steady state. The discount factor targets a capital-output ratio of about 3 at annual frequency. In the open economy households hold about a quarter of their wealth abroad (endogenously, at a disaster risk of $p=1\%$), so a higher discount factor is needed for the same domestic capital stock: $\beta = 0.985$, against $\beta = 0.9815$ in the closed economy.¹⁰ Both economies then have the same capital stock and an annual return of about 2.35 percent in the deterministic steady state. In the open economy, the foreign position follows the rule (22) with $\eta_F = 10$: a return premium of one percentage point per quarter moves 10 percent of household wealth home within the quarter. With these values the open economy's capital stock is back on its no-disaster path within about four years after a macro disaster (Figure 3). The disaster is sized on wars (Luetticke et al., 2025): about 10 percent of the capital stock is destroyed directly and about 20 percent cumulatively, profits fall persistently, and productivity falls by enough that output is about 10 percent lower over three years.

We choose relative risk aversion γ and the concentration of losses, d , jointly in order to match the survey pattern of section 2: when the annual disaster probability rises by one percentage point, the active saving rate of the top 20 percent rises by about 10 basis points more than that of the bottom 80 percent, whose response is close to zero. The two parameters play different roles. The concentration of losses sets the gap: with $\gamma = 5$ in the closed economy it is 10.4 basis points at $d = 0.6$, 13.1 at $d = 0.7$ and 15.9 at $d = 0.8$. Risk aversion raises the precautionary saving of all groups together and so sets the level of the responses, in particular that of the bottom 80 percent. We use $\gamma = 5$ and $d = 0.6$ in both economies. The gap is then 10.4 basis points in the closed and 7.3 in the open economy, with a response of the bottom 80 percent of +1.3 and -1.2 basis points, respectively.

5 Model results

In the main experiment, we raise the annual disaster probability from $p = 1\%$ to $p = 2\%$. We report two sets of moments. The *saving responses* are partial-equilibrium (PE) responses: holding prices at the $p = 1\%$ risky steady state, we compute the change in the active saving rate of each wealth group, in basis points

¹⁰Capital is measured as in the national accounts: the fixed assets located in the domestic economy, whoever owns them (see, e.g., U.S. Bureau of Economic Analysis, 2026), related to domestic output. Households' holdings of foreign assets are not part of it.

Table 1: Calibration (quarterly)

parameter	description	value	source / target
<i>Households and technology</i>			
β	discount factor	0.9815 / 0.985	$K/Y \approx 12$ (closed / open economy)
γ	relative risk aversion	5	survey pattern (Section 2)
ρ_h, σ_h	labor productivity	0.98, 0.139	standard
α	capital share	0.346	standard
δ_0	depreciation	0.0215	standard
μ_Y	profit share	0.05	Wealth-Gini 0.75
ι	entrepreneur exit	0.0063	spells of about 40 years
$\zeta/(\zeta + \iota)$	entrepreneur mass	0.01	Mian et al. (2020)
h^E	entrepreneurs' labor productivity	0.3	low but positive
<i>Disaster</i>			
p	annual probability	1%, 2%	see Section 6
D	destruction on impact	0.10	Luetticke et al. (2025): about 10% direct
d	loss-given-hit	0.6	survey gap (section 2); $d = D$ uniform
ρ_δ	persistence of destruction	0.53	cumulative destruction about 20%
D_Z, ρ_Z	TFP loss, persistence	0.07, 0.841	10% output loss over 3 years (closed economy)
ψ, ρ_μ	profit squeeze, persistence	0.6, 0.966	dividend loss after wars Luetticke et al. (2025)
<i>Open economy</i>			
R^*	safe foreign return	1.0047	about 1.9% p.a.
η_F	repatriation: premium elasticity	10	4-year regeneration of capital stock

Notes: The closed and the open economy share all parameters except β and the open-economy block. The concentrated (natural-disaster) disaster sets $\rho_\delta = D_Z = \psi = 0$ and $d = 0.8$. Section 5 reports robustness for other values of γ and d .

of income, with active saving truncated at zero as in the survey. The *inequality response* is the change in the wealth Gini (in Gini points, i.e. times 100) and in the top 10 percent wealth share (in percentage points) between the risky steady states at $p = 1\%$ and $p = 2\%$, both solved in general equilibrium. Throughout, B80 denotes the bottom 80 percent of the wealth distribution, and T20, T10 and T1 the top 20, 10 and 1 percent.

5.1 Disasters of the natural-disaster type: concentrated losses

We start with a disaster that destroys 10 percent of the capital stock on impact, without persistent destruction, productivity loss or profit squeeze, and vary how concentrated the losses are. At $d = 0.8$, 12.5 percent of households are hit and lose 80 percent of their wealth; at $d = 0.1$ the loss is uniform. Such a disaster lowers GDP by less than 2 percent: it is a disaster for the households it hits, not for the economy.

Table 2 shows that, in the closed economy, concentration is a powerful source of wealth inequality. At the same expected destruction, the risky-steady-state Gini is 3.2 points higher when 12.5 percent of households lose 80 percent of their wealth than when everybody loses 10 percent. The level effect is convex in d but smooth: already at $d = 0.5$ it amounts to one Gini point.

The mechanism is the polarization of saving that the analytical model predicts

Table 2: Concentrated disasters: inequality and saving responses

d	level at $p = 2\%$		ΔGini per pp of p				PE, $p : 1 \rightarrow 2\%$ (bp)		
	Gini	vs. uniform	$0 \rightarrow 1\%$	$1 \rightarrow 2\%$	$2 \rightarrow 3\%$	$3 \rightarrow 4\%$	B80	T20	T1
<i>Closed economy (one asset), $D = 0.10$</i>									
0.1	0.744	—	+0.06	−0.05	−0.09	−0.11	+2.1	+4.1	+19
0.5	0.754	+1.0	+0.76	+0.28	+0.11	+0.03	−1.5	+4.8	+85
0.8	0.776	+3.2	+2.48	+0.70	+0.32	+0.16	−9.7	+4.5	+220
<i>Open economy, $D = 0.10$</i>									
0.5	0.755	NA	NA	−0.11	0.00	−0.15	+0.7	+3.2	+22
0.8	0.757	NA	NA	+0.01	−0.05	0.00	+0.2	+6.7	+75

Notes: Disaster destroys a fraction D of capital on impact only, loss-given-hit d ($d = 0.1$ is uniform). “Level”: wealth Gini in the risky steady state at $p = 2\%$, and its difference to the uniform disaster in Gini points. ΔGini : change between risky steady states, Gini points per percentage point of annual disaster probability. PE: change in the truncated active saving rate in basis points of income, wealth groups by exact quantiles. Open economy: at $p = 0$ the portfolio choice is not defined; under the uniform disaster almost all households switch between domestic capital and the safe asset at the same return, so that no risky steady state exists on the grid of portfolio shares. Differences below about 0.1 Gini points are within numerical noise.

once the loss is large relative to a household’s buffer. For a household with little wealth, a loss of 80 percent of that wealth is a small loss of income; for a household that lives off its wealth, it is a large one. Since risk exposure, as defined in Section 3, is a function of marginal utility in times of the disaster, which is highly convex for the calibrated $\gamma = 5$, concentration raises the exposure of the wealthy by much more than that of the poor. A higher disaster probability therefore lowers the active saving rate of the bottom 80 percent, by 9.7 basis points at $d = 0.8$, and raises that of the top 20 percent, by 4.5 basis points, and that of the top 1 percent by 220 basis points. The Gini rises by 0.70 points at $d = 0.8$ and by 0.28 points at $d = 0.5$, while a uniform disaster leaves it unchanged or lowers it slightly. The response is also concave in p : the first percentage point of risk raises the Gini by 2.5 points at $d = 0.8$, three to four times as much as the second.

Portfolio choice: two additional channels, offsetting each other. In the open economy the same disaster has almost no effect on inequality: per percentage point of p , the Gini changes by between -0.15 and $+0.01$ points, within numerical noise of zero. The saving responses keep the survey’s sign pattern: the bottom 80 percent barely respond ($+0.2$ and $+0.7$ basis points at $d = 0.8$ and $d = 0.5$), while the top 20 percent raise their saving rate by 6.7 and 3.2 basis points. The polarization of saving is still there, but the wealthy now have a second margin. At given prices, higher disaster risk makes them move part of their wealth from domestic capital into the safe foreign asset: at $d = 0.8$, the share of direct capital in the wealth of the top

20 percent falls from 0.70 to 0.56. The safe asset earns less than domestic capital in normal times, so the wealthy accept a lower return on a larger part of their wealth, and their wealth grows more slowly than that of the rest of the distribution. *This is the first additional channel with portfolio choice.* Quantitatively, the portfolio shift lowers the Gini by 0.23 points and offsets the polarization of saving, which alone would raise it by 0.19 points (at $d = 0.5$: -0.08 and $+0.05$). The wealthy insure through their portfolio rather than through accumulation.

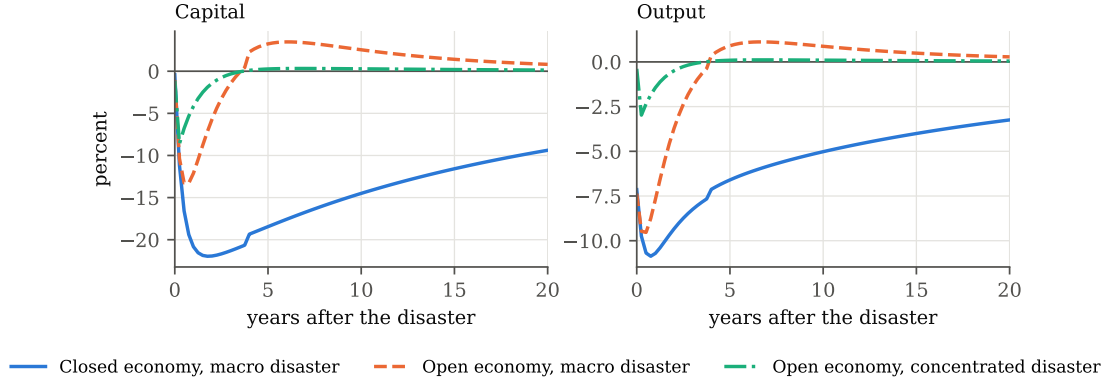
The portfolio shift also has a general-equilibrium effect, which is as large as the partial-equilibrium effects and works in the opposite direction. Wealth that moves into the safe asset leaves the domestic capital stock: between $p = 1\%$ and $p = 2\%$, domestic capital falls by 2.9 percent at $d = 0.8$ and by 2.4 percent at $d = 0.5$. The return on capital rises by 21 basis points a year and the wage falls by 1 % (17 basis points and 0.9 % at $d = 0.5$). This redistributes from wage earners to capital owners and raises the Gini by 0.33 points at both values of d , more than the polarization of saving does at given prices. *This is the second channel through which portfolio choice affects wealth inequality.* Quantitatively, for the concentrated disaster shock, it is offset by the post-disaster dynamics: re-solving the continuation at $p = 2\%$ lowers the Gini by 0.27 points at $d = 0.8$ and 0.34 points at $d = 0.5$, mostly through saving, as the bottom 80 percent save about 4 basis points more.

The repatriation of foreign assets after a disaster largely determines the post-disaster continuation in the open-economy setup. Repatriation insures wage earners and therefore works in favor of inequality. At the baseline speed ($\eta_F = 10$), capital is largely rebuilt within two years (Figure 3), and the wage is 1.8% below its no-disaster path after one year and 0.7% after two. When repatriation is slowed to $\eta_F = 1$, capital is still 5% and the wage 1.8% below that path after five years. The bottom 80 percent then raise their saving rate by 2.3 basis points instead of 0.2, and higher disaster risk lowers the Gini by 0.18 points. Faster repatriation, however, does not raise the effect further. At $\eta_F = 20$ and $\eta_F = 100$ the Gini response is -0.03 and -0.02 points, although at $\eta_F = 100$ capital and wages are back on their no-disaster path within a year and the bottom 80 percent's saving response falls to -0.5 basis points. At the baseline speed, the wage loss after a concentrated disaster is already too small and too short-lived to move the saving of wage earners much.

5.2 Macro disasters in the closed economy

We now turn to the macro disaster, which we calibrate to destroy 10 percent of the capital stock on impact and about 20 percent cumulatively, together with a persistent productivity loss and a profit squeeze. The disaster lowers output by about 10 percent over three years, in line with typical thresholds in the literature.

Figure 3: Capital and output in a disaster realization



Notes: Generalized impulse responses (path after a disaster minus path without a disaster, both from the risky steady state at $p = 2\%$), percent. Closed economy, macro disaster: one asset, $d = 0.6$. Open economy, macro disaster: $d = 0.6$, same primitive shock. Open economy, concentrated disaster: $d = 0.8$, destruction on impact only ($D = 0.10$). The kink after four years marks the hand-off from the 16 exactly computed quarters to the first-order continuation (Appendix C.3). Table A2 in Appendix A reports the responses of output, consumption, investment, capital, the wage and wealth inequality at selected horizons.

The upper panel of Table 3 reports the results. Because the macro disaster hits everybody through capital returns and wages, it tends to raise precautionary saving across the board. The saving rate-gap between the top 20 and the bottom 80 percent is set by concentration: it rises from 6.6 basis points at $d = 0.4$ to 15.9 at $d = 0.8$, and it reaches the survey's 10 basis points at $d = 0.6$, where the bottom 80 percent's response is +1.3 basis points, close to the survey's null. Risk aversion (not shown in the table) shifts the responses of all groups together and leaves the gap almost unchanged: at $d = 0.6$, lowering γ from 5 to 4.5 moves the bottom 80 percent's response from +1.3 to -0.5 basis points and the top 20 percent's from 11.8 to 9.9, maintaining a gap of 10.4 and 10.3.

At the main calibration ($\gamma = 5$, $d = 0.6$), a 1 percentage point higher disaster risk raises the wealth Gini by 0.22 points and the top 10 percent wealth share by 0.27 percentage points. The inequality response rises with concentration, to 0.36 points at $d = 0.7$ and 0.49 points at $d = 0.8$, where the bottom 80 percent cut their saving by 0.8 and 3.6 basis points.

The general-equilibrium response of prices dampens the effect only slightly. Higher disaster risk raises precautionary saving and the capital stock, and lowers the return on capital. A lower return hurts those whose income comes from wealth, which equalizes; but at the calibrated concentration of risk the polarization of saving dominates.

Table 3: Macro disasters: inequality and saving responses to $p : 1\% \rightarrow 2\%$

d	ΔGini	$\Delta\text{top } 10\%$	B80	T20	T20–B80	T10–B90	r (% p.a.)
<i>Closed economy (one asset)</i>							
0.40	−0.02	−0.01	+4.1	+10.7	+6.6	+10.8	2.20
0.50	+0.09	+0.12	+2.9	+11.2	+8.3	+14.3	2.15
0.60	+0.22	+0.27	+1.3	+11.8	+10.4	+19.0	2.09
0.70	+0.36	+0.44	−0.8	+12.3	+13.1	+25.1	1.99
0.80	+0.49	+0.60	−3.6	+12.3	+15.9	+31.7	1.85
<i>Open economy</i>							
0.40	+0.24	+0.37	−0.9	+4.6	+5.5	+10.6	2.12
0.50	+0.17	+0.28	−1.1	+5.2	+6.3	+12.1	2.16
0.60	+0.12	+0.21	−1.2	+6.1	+7.3	+14.0	2.20
0.70	+0.19	+0.31	−1.3	+7.5	+8.8	+16.6	2.24
0.80	+0.22	+0.36	−1.1	+9.8	+10.9	+20.6	2.29

Notes: Macro disaster ($D = 0.10$, $\rho_\delta = 0.53$, $D_Z = 0.07$, $\psi = 0.6$ with half-life 5 years), $\gamma = 5$. Closed economy: one asset. Open economy: portfolio choice; entrepreneurs hold all their wealth in their own firm. Bold: main calibration. ΔGini in Gini points, $\Delta\text{top } 10\%$ in percentage points, both between the risky steady states at $p = 1\%$ and 2% . Saving responses in basis points of income (PE, truncated active saving, wealth groups by exact quantiles). r : annual return in the risky steady state at $p = 1\%$; the closed economy’s deterministic steady state has 2.35%. Differences below about 0.1 Gini points are within numerical noise.

5.3 Macro disasters in the open economy

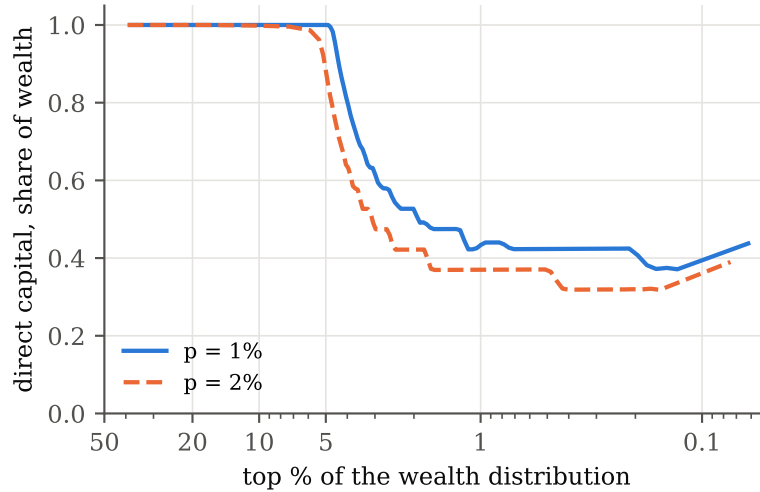
In the open economy, households can hold part of their wealth in a safe foreign asset. The primitive disaster is the same as in the closed economy; what changes is that households have a second margin to respond to disaster risk, their portfolio, and that the economy can rebuild its capital stock after a disaster by repatriating foreign assets.

Foreign assets cushion the disaster. Figure 3 and Table A2 in Appendix A compare the disaster’s effects at the main calibration. In the closed economy, output falls by 10.9 percent in the first year and the capital stock is still 15 percent below its no-disaster path after ten years. In the open economy, investment rises by about 70 percent in the first year as foreign assets are repatriated, the capital stock is back above its no-disaster path within five years, and the three-year output loss is 8.8 percent rather than 10.2 percent. Consumption falls by 4 percent instead of 8. The concentrated disaster costs 1.9 percent of output over three years, and capital is largely rebuilt within two years.

The lower panel of Table 3 reports the inequality response in the open economy. The survey pattern holds throughout (the gap between the top 20 and the bottom 80 percent is 5.5 to 10.9 basis points, with the bottom’s response between -1.3 and -0.9), and higher disaster risk raises the wealth Gini by 0.12 to 0.24 points. At the

main calibration ($d = 0.6$: B80 -1.2 , T20 $+6.1$ basis points, a gap of 7.3), the Gini rises by 0.12 points and the top 10 percent share by 0.21 points. The effect is thus smaller than in the closed economy, where the same calibration gives 0.22 points, and it is the result of opposing forces, the same we highlighted in Section 5.1.

Figure 4: Endogenous portfolio choice over the wealth distribution



Notes: Open economy ($\gamma = 5$, $d = 0.6$), risky steady states at $p = 1\%$ and $p = 2\%$. Share of wealth held as direct domestic capital (the rest is held in the fund, i.e. the safe foreign asset), wealth-weighted at each point of the wealth grid, workers only; entrepreneurs hold all of their wealth in their own firm. Horizontal axis: position in the wealth distribution (log scale). The steps reflect the discrete grid of portfolio shares.

Portfolio choice lowers inequality through costly risk premia. At given prices, higher disaster risk makes wealthy households move from domestic capital into the safe asset: the top 20 percent's share of direct capital in their wealth falls from 0.69–0.84 to 0.35–0.66. The safe asset earns less in normal times, and the wealthy give up that return on a large part of their wealth. This portfolio shift lowers the Gini by 0.17 to 0.56 points and offsets much of the polarization of saving, which alone would raise it by 0.34 to 0.62 points. This is how openness depresses the inequality effect of disaster risk: the wealthy insure through their portfolio rather than through accumulation. Figure 4 shows the portfolio choice across the wealth distribution. Households below the top 5 percent hold only domestic capital: for them the equilibrium risk premium outweighs the risk. Above, the share of direct capital falls with wealth, to below one half in the top 1 percent, because the wealthy are the households whose consumption is most exposed to a disaster. A higher disaster probability shifts the whole schedule down and moves the point where households start to diversify further down the distribution.

Portfolio choice raises inequality through a general equilibrium effect.

The portfolio shift moves capital abroad. The domestic capital stock falls, the return on capital rises and the wage falls, which raises the Gini by 0.32 to 0.65 points. Who earns the higher return decides the sign of the overall effect. Crucially, entrepreneurs cannot diversify their wealth by assumption, so the top 1 percent keeps its full exposure to the domestic return. Third, the continuation adjusts: at the higher risk, a disaster strikes an economy with less domestic capital and a higher return, which makes it less costly for capital-rich entrepreneurs and lowers their precautionary saving; this lowers the Gini again by 0.30 to 0.38 points.

The positive response in the open economy therefore rests on a financial friction. In a model variant where entrepreneurs can diversify into the fund, they then keep only 32 to 47 percent of their wealth in their own firm. Consequently, the response of the Gini turns negative (-0.16 to -0.44 points for d between 0.4 and 0.6, -0.44 at the main calibration), and the survey pattern of saving responses narrows (to a gap of about 4 basis points). In a model with portfolio choice and return spreads, the effect of disaster risk on inequality thus mainly runs through returns, and the sign of this effect depends on who bears the domestic risk, and thus earns the return spread. Table A3 in Appendix A provides a decomposition of the different effects of portfolio choice on the inequality-response to disaster risk over a range of calibrations.

5.4 Realized disasters

The risky steady state captures the anticipation of disasters. A realized disaster has its own effect on inequality, shown in the last rows of each panel of Table A2 in Appendix A. Concentrated losses raise the Gini on impact, by one to two points, because hit households fall down the distribution: the idiosyncratic component of disasters mechanically disperses the distribution, and thus increases inequality. Afterwards, the macro disaster reduces inequality: ten years in, a realized disaster decreases the Gini by 2.0 points in the closed, and 1.1 points in the open economy; the top 1 percent wealth share falls by 1.2 percentage points after ten years and 2.3 percentage points after twenty years in the closed economy (0.7 and 1.5 percentage points in the open economy). The profit squeeze, which hits entrepreneurs, carries most of this leveling. Luetticke et al. (2025) find that wars lower the top 1 percent wealth share by up to 10 percent after fifteen years, about two thirds of it through destruction; our model accounts for a substantial part of this decline without the tax increases that account for the rest in their analysis.

Ex ante, disaster risk raises inequality; ex post, a realized disaster lowers it. With a disaster probability of 1 to 2 percent a year, the ex-ante effect dominates the average distribution: at the main calibration and $p = 2\%$, the mean Gini, which

weights the risky steady state and the post-disaster paths by their probabilities, is 0.03 to 0.04 points below the risky-steady-state Gini.

5.5 Summary

At the main calibration, which matches the survey evidence that the top 20 percent raise their saving and the bottom 80 percent do not, a one percentage point higher annual disaster probability raises the wealth Gini by 0.22 points in the closed and by 0.12 points in the open economy, and by up to half a point with more concentrated losses. Concentrated disasters of the natural-disaster type raise inequality through a polarization of saving in the closed economy, strongly when losses are concentrated and the probability is low (0.28 to 0.70 Gini points per percentage point between $p = 1\%$ and 2% at $d = 0.5$ to 0.8 , more from $p = 0$), but hardly at all in the open economy, where capital flows rebuild the capital stock within two years. The model with portfolio choice between local and foreign assets predicts that disaster risk against which households can buy insurance is both less harmful ex post (the output loss is attenuated), and induces less inequality ex ante (0.12 to 0.25 points). While the portfolio shift towards safe assets harms the productivity of the capital stock¹¹, which raises inequality through factor prices, the quantitatively more important effect is the lower portfolio return of richer households, who pay the risk premium in order to shield themselves partly from the direct effect of the disaster.

6 Disaster risk and wealth inequality in the data

In the final part of the paper, we compare the model’s predictions with the empirically observed relation between disaster risk and wealth inequality. Following the model’s distinction between more concentrated disasters and macro-disasters, we investigate two different settings: For disasters of the natural-disaster type, we use variation in exposure to natural hazards across U.S. states and commuting zones. For macro disasters, we estimate GDP tail risk in a panel of 42 countries, following [Marfè and Pénasse \(2024\)](#). In both cases we attempt to quantify the empirical slopes in the units of the model.

¹¹In our model, we consider the outflow to foreign assets. A qualitatively similar effect can be expected from a flow towards more liquid assets, which are often modelled as less productive than illiquid capital ([Bayer et al., 2019](#)).

6.1 Natural disaster risk across U.S. regions

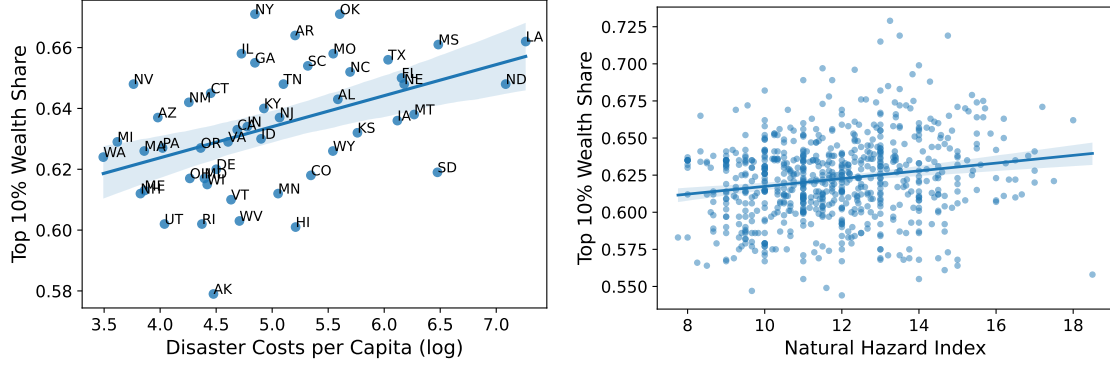
Natural hazards vary across U.S. regions for geographic reasons, which makes reverse causality from inequality to the hazard implausible.¹² We combine measures of natural-disaster risk with the spatial wealth-inequality data of [Suss et al. \(2024\)](#), which provide the top 10 percent wealth share and the wealth Gini for U.S. states and commuting zones in 2020.

States. We measure natural-disaster risk at the state level by the average cost of billion-dollar natural disasters per capita since 1980, from the National Centers for Environmental Information. Specification (1) in Table 4 and the left panel of Figure 5 show that a one standard deviation higher (log) disaster cost goes with a 0.9 percentage point higher top 10 percent wealth share; disaster risk explains about a fifth of the cross-state variation in wealth concentration.

Commuting zones. For 722 commuting zones we use the multi-natural-hazard index of the National Center for Disaster Preparedness, which rates the exposure of each county to eleven hazards (among them hurricanes, floods, wildfires, tornadoes, droughts and earthquakes) as absent, low, medium or high; we average it over a zone’s counties. The index is an ex-ante measure of exposure: it does not count realized events. A one standard deviation higher exposure goes with a 0.5 percentage point higher top 10 percent share (specification (2) in Table 4) and a 0.5 point higher wealth Gini. The relation holds within states: with state fixed effects the slope is unchanged (0.47 Gini points per standard deviation), and it falls only to 0.37 when we control for realized disasters, measured by FEMA disaster declarations.

¹²While the hazard is exogenous, the exposure is not: where households live and how much they adapt depends on their wealth ([Fried, 2022](#)). We allow for idiosyncratic disaster insurance by households, but abstract from financial constraints that may concentrate the risk of a natural disaster on poorer households. Given our analysis, we expect this channel to mitigate the effect of natural disaster risk on wealth inequality. Nonetheless, we find significant positive effects in the data.

Figure 5: Wealth inequality and natural disaster risk across U.S. regions



Notes: Left panel: top 10% wealth share in 2020 and the logarithm of the average cost of natural disasters per capita since 1980, by U.S. state (N=50). Right panel: top 10% wealth share in 2020 and the natural-hazard index, by commuting zone (N=722). Wealth inequality from [Suss et al. \(2024\)](#).

Table 4: Wealth inequality and natural disaster risk: U.S.

	(1)	(2)
Avg Disaster Cost	0.0092*** (0.003)	
Natural disaster risk index		0.0053*** (0.001)
Constant	0.6336*** (0.003)	0.6222*** (0.001)
N	50	722
Adj. R-Squared	0.188	0.036

Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors in parenthesis. Dependent variable: Top 10% wealth share, per region. Avg. Disaster Cost is in logs. Both regressors are standardized.

In model units. To compare these slopes with the model, we translate the hazard measures into expected capital destruction per year, the model's pD . In the model, one percentage point of annual disaster probability at $D = 0.10$ destroys 0.1 percent of the capital stock a year in expectation. At the state level, we divide the disaster cost per capita by the building value per capita from FEMA's National Risk Index; across states the hazard index maps into FEMA's expected annual building-loss rate at 0.02 percent a year per index point. With these conversions, an increase in expected destruction of 0.1 percent of capital a year goes with a wealth Gini higher by about 0.6 points across states and about 1.2 points across commuting zones (also within states), and with a top 10 percent share higher by 0.7 and 1.4 percentage points, respectively.

These magnitudes are comparable to the model's prediction for concentrated dis-

asters. In the local regime of Section 5.1, the same increase in expected destruction raises the Gini by 0.3 to 0.7 points between $p = 1\%$ and 2% (Table 2), and by more at lower levels of risk. The natural hazards in U.S. states are arguably of this type: concentrated on few households, and small for the state-economy as a whole. On the commuting zone level, natural disasters will have more of an aggregate impact, so the results from Section 5.3 apply. For highly concentrated disasters, the model explains a Gini increase of about 0.2 points, and a top 10 percent share increase of about 0.4 percentage points.

Finally, we find that realized disasters, measured by FEMA declarations or by realized costs, also increase inequality. This is in line with the model’s prediction that concentrated losses raise inequality on impact (Section 5.4).

6.2 GDP tail risk across countries

For disasters of the macro type, we measure disaster risk as tail risk in GDP growth. We build on the method of Marfè and Pénasse (2024). They estimate, for a panel of 42 countries since the late 19th century, a ridge-penalized quantile regression of the left tail of three-year GDP growth on a set of predictors $X_{i,t}$,

$$Q_\tau(g_{i,t+3} \mid X_{i,t}) = X_{i,t}B_\tau, \quad \tau \in [0.01, 0.5], \quad (23)$$

where $g_{i,t+3}$ is three-year GDP growth standardized by its country-specific mean and standard deviation over a rolling window. The coefficients B_τ are common to all countries, so the approach leverages the panel dimension. The predictors are lagged indicators of recessions at home and abroad, consumption growth, wars, civil wars and political crises at home and abroad, natural disasters, famines, banking and currency crises, sovereign defaults, hyperinflations, world credit growth and U.S. asset-price indicators. Fitting a log-linear function $g_{i,t}(\tau) \approx \hat{Q}_\tau(\cdot \mid X_{i,t})$ over the estimated quantiles and evaluating its inverse at -2 gives the probability that three-year growth falls more than two standard deviations below its mean,

$$\hat{p}_{i,t} = g_{i,t}^{-1}(-2). \quad (24)$$

We average $\hat{p}_{i,t}$ over 1987 to 2013, the period in which the estimate is available for all countries. Average tail risk is 3.74 percent, with a cross-country standard deviation of 0.71 percentage points; it is lowest in Taiwan and China and highest in Colombia and Venezuela.

Tail risk and wealth inequality. We relate tail risk to wealth inequality, measured as the 1995–2022 average of the wealth Gini and of the top 10 percent wealth

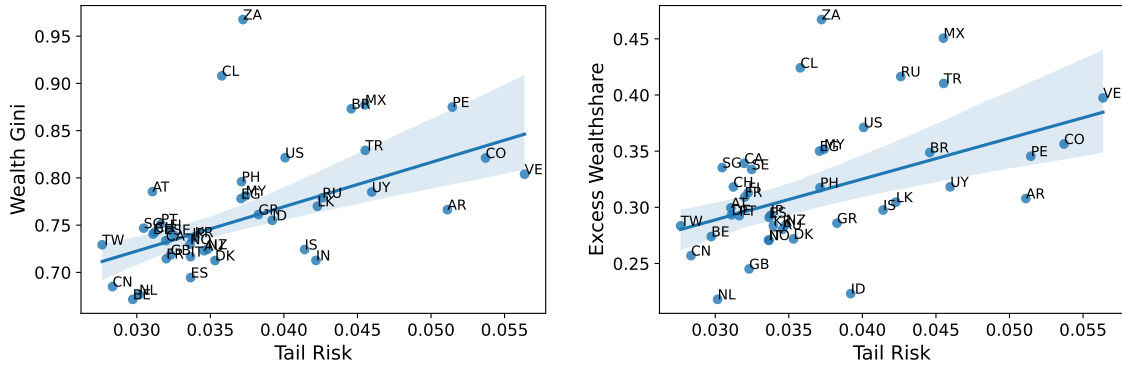
share from the World Inequality Database. Table 5 and Figure 6 show the results. A one percentage point higher tail risk goes with a 4.8 point higher wealth Gini and a 6.6 percentage point higher top 10 percent wealth share. Wealth inequality partly reflects inequality in labor income, which our model holds constant. Controlling for the top 10 percent share of labor income (from the International Labour Organization, 2004–2020) lowers the slope for the top 10 percent wealth share to 3.6 percentage points per percentage point of tail risk, still highly significant.

Table 5: Wealth inequality and GDP tail risk

	Wealth Gini		Top 10% wealth share	
	(1)	(2)	(3)	(4)
Tail risk	4.7793*** (1.1916)	4.0772*** (1.2615)	6.6194*** (1.5149)	3.5631*** (1.2437)
Wage inequality		0.1995 (0.1319)		1.1139*** (0.1885)
Constant	0.5865*** (0.0453)	0.5511** (0.0504)	0.3736*** (0.0576)	0.1524** (0.0565)
Excluding India	no	yes	no	yes
N	42	41	42	41
Adj. R^2	0.292	0.269	0.306	0.631

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Dependent variable: wealth Gini in columns (1) and (2), top 10% wealth share in columns (3) and (4). Wage inequality denotes the wage share of the highest decile of wage earners. Columns (2) and (4) exclude the outlier India.

Figure 6: Wealth inequality and GDP tail risk



Notes: Left panel: wealth Gini and GDP tail risk (N=42). Right panel: excess wealth share, the top 10% wealth share minus the top 10% labor income share, and GDP tail risk (N=41, without India).

Comparison to the model. The conditional slope is about five to eight times the model's prediction for macro disasters. In the closed economy, one percentage point

of annual disaster probability raises the top 10 percent wealth share by 0.43 to 0.63 percentage points (Table 3); the data give 3.6 percentage points per percentage point of tail risk, conditional on labor-income inequality. For the Gini, the conditional slope is 2.7 to 4.1 points, depending on the sample, against 0.36 to 0.52 points in the model. Three reasons suggest that the cross-country slope overstates the causal effect of disaster risk. First, omitted variable bias is likely to overstate the effect, as tail risk is part of a syndrome of weak institutions, high inflation and closed capital accounts, which can raise wealth concentration directly (Table 6). Second, inequality may itself cause part of the disaster risk, for instance through the fragility of bank funding (Isojärvi and Jerow, 2026), which biases the slope upward. Third, the disasters that the tail-risk measure captures are larger than the model's. Because the country-specific standard deviations are estimated over windows that include wars and depressions, the two-standard-deviation threshold for three-year GDP growth ranges from 8.5 percent (United Kingdom) to 28 percent, with a median of about 15 percent: a disaster of the model's size registers as a tail event only in the more stable economies in the sample.

Table 6: The tail-risk slope with additional controls

additional control	corr. with tail risk	top 10% W	wealth Gini
none		3.56***	4.12***
log GDP per capita, 1965	−0.24	3.10**	4.09***
log GDP per capita	−0.53	3.72***	4.20***
rule of law (WGI)	−0.70	3.08*	3.74**
capital-account openness	−0.53	2.58*	3.52**
private credit / GDP	−0.67	3.83**	4.84***
inflation (log mean)	+0.68	3.27*	2.84
Latin America	+0.73	2.98*	1.72
<i>joint</i>		1.61	0.34

Notes: Coefficient on GDP tail risk in cross-country OLS regressions of country averages, with one additional control per row. All regressions control for the top 10% share of labor income (ILO). Top 10% W: without India, N = 39 to 41; wealth Gini: N = 40 to 42. “None” on the common sample of the rule-of-law row (40 and 41 countries). *p<0.10, **p<0.05, ***p<0.01. Data: Penn World Table 10.01, World Bank (WDI, WGI), Chinn and Ito (2006). The last row (*joint*) adds GDP per capita, rule of law, openness, inflation, resource rents and the Latin America dummy jointly.

Robustness. The conditional slope is robust to single controls (Table 6): for the top 10 percent wealth share, it stays between 2.6 and 3.8 for every single control we consider (between 1.7 and 4.8 for the wealth Gini), including predetermined GDP per capita. Jointly, development, institutions, openness, inflation, resource rents and a Latin America dummy absorb the variation explained by tail risk and the labor income share; the R^2 of the joint regression increases only by about 10bp. With 40 countries and correlations of about 0.7 between tail risk and these controls,

the cross-section cannot separate tail risk from the other controls, and standard errors widen. Conditional on tail risk, most controls have no robust own effect. Capital-account openness is the exception for the top 10 percent share (more open economies have less concentrated wealth, also in the joint regression), which fits the effect of openness in the model (see Section 5.3). For the wealth Gini, only the Latin America dummy comes close to significance.

Which sources of disaster risk matter for inequality. The tail-risk measure is built from observable predictors, which allows us to ask which kinds of disaster risk make a country’s tail risk high, and which of them covary with wealth inequality. For each category of predictors, we set the predictors to their sample mean, recompute tail risk, and attribute the difference to that category. Table 7 shows the result.

Table 7: Sources of cross-country differences in GDP tail risk

category	share of cross-country variance	corr. with top 10% W	slope without the category	
			top 10% W	wealth Gini
all (baseline)			3.54***	4.04***
macro	27%	0.16	3.79**	3.29*
war, instability	32%	0.47	2.96*	4.33***
natural disasters	−1%	−0.16	3.49***	3.98***
financial	40%	0.40	5.98***	6.70***
banking crises	7%	−0.06	4.37***	4.62***
hyperinflation	26%	0.48	4.21**	5.17***
U.S. asset prices	15%	0.53	3.96***	4.32***

Notes: Contribution of a category: country-average tail risk (1987–2013) minus its counterfactual with the category’s predictors at their sample mean. Variance shares do not sum to one because tail risk is nonlinear in the predictors. Slopes: coefficient on tail risk without the category in OLS regressions that control for the top 10% share of labor income (ILO); top 10% W without India (N = 41), wealth Gini N = 42. *p<0.10, **p<0.05, ***p<0.01. Categories of predictors: macro: recessions, consumption growth; war, instability: war and political instability; natural disasters: natural disasters and famine; financial: banking and currency crises, sovereign default, hyperinflation, world credit growth (banking crises and hyperinflation also shown separately).

War and political instability, at home and abroad, are the risk factors most robustly related to wealth inequality. They account for about a third of the cross-country variance in tail risk and are the only category whose removal lowers the inequality slope materially; in a joint regression on all category contributions, only war and political instability is significant for the top 10 percent share. Financial conditions account for the largest share of the variance in tail risk, but mostly through hyperinflation. Measures of financial fragility proper—banking crises and world credit growth—contribute about 5 percent of the variance and are unrelated to wealth concentration: removing them *raises* the inequality slope. In the panel, banking crises (0.31 percentage points per standard deviation, $p = 0.28$) and world

credit growth (0.18, $p = 0.62$) do not predict GDP disasters once the other predictors are included, while civil wars, wars and political crises abroad, recessions abroad and famines do. The same holds for country-level fragility on the post-1950 sample: neither bank non-core funding (data from [Grimm, 2024](#); 0.24 percentage points per standard deviation, $p = 0.61$) nor credit booms (0.25, $p = 0.66$) predict GDP disasters, and non-core funding is unrelated to wealth inequality across countries.

To summarize, our regression analysis of the inequality-effect of GDP tail risk suggests that sources of disaster risk that covary with wealth inequality are those of weak states—war risk, political violence and expropriation-type monetary and fiscal crises—, while the fragility of intermediaries, a propagation channel of financial crises often discussed in the literature, shows no systematic relation.

7 Conclusion

Wealth is very unequally distributed in most countries, and its variation across countries is only partly explained by labor income differences. In this paper, we ask whether the aggregate risk of disasters can account for a part of the residual.

At the microeconomic level, we make use of an information treatment in a representative survey of German households and find that higher perceived disaster risk induces the wealthiest 20 percent to raise their saving rates, while the bottom 80 percent show a weakly negative response. A standard consumption-savings problem can explain this pattern, provided one assumes a low enough elasticity of intertemporal substitution and accounts for labor income as a source of income besides capital. We then build a heterogeneous-agent model that features both idiosyncratic and aggregate risk, which allows us to make the link from heterogeneous saving rate-responses to changes in aggregate wealth inequality. We find that the heterogeneity in disaster risk exposure across the wealth distribution is key. In addition to the difference between labor and capital income, we find important roles both for the continuation after the disaster, in terms of the recovery of factor prices and profits, and for the endogenous portfolio choice between risky and safe assets by households.

When we calibrate the model to the partial equilibrium evidence from the survey, we find that a one percentage point higher annual disaster probability raises the wealth Gini by up to about half a point. We consider two disaster types, more concentrated disasters with a modest aggregate effect, and macro disasters that lower annual output by 10 percent over three years. Disasters that are more concentrated are individually more risky, and therefore induce higher wealth inequality *ex ante*. We also find that the ability of households to insure against disasters by holding foreign assets reduces the effect through risk premia that lower the wealthy household’s portfolio returns.

Linking these hypotheses to the data, we find that regions of the United States more exposed to natural hazards have higher wealth inequality, of a magnitude comparable to the model. Across countries, GDP tail risk is significantly related to wealth concentration, with a slope five to eight times as high as the model predicts for macro disasters, even conditional on labor-income inequality. GDP tail risk explains up to 63% of the cross-country variation in wealth inequality and is robust to country-level controls. In line with the model, the inequality-effect of disaster risk falls with a country's openness. Our regression analysis suggests that political and expropriation risks might render disasters even riskier for wealthier households than we account for in the model, implying a higher ex ante effect on wealth inequality. One interesting test for this would be to collect survey evidence about saving rate responses to disaster risk for countries that differ from Germany in terms of those political risks.

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A Additional Tables and Figures

Table A1: Robustness: difference between the top 20 and the bottom 80 percent per percentage point of annual disaster probability (basis points)

	Financial crisis	Pandemic	China– Taiwan war	Energy crisis	Pooled
Baseline	14** [0.5, 81]	12 [−7.7, 104]	0.9 [−15, 17]	5.5 [−3.8, 18]	7.4** [0.6, 16]
Drop large purchases	14* [−1.3, 74]	7.2 unbounded	3.9 [−9.4, 20]	9.2* [−0.2, 26]	8.2** [0.9, 18]
Drop interrupted	20* unbounded	11* [−2.1, 39]	7.7 [−5.2, 24]	1.7 [−10, 14]	8.3** [1.7, 17]
Drop both	20* unbounded	9.3 [−6.3, 40]	8.0 [−3.4, 23]	5.8 [−5.8, 22]	9.3** [2.6, 18]
IPW	18** [5.0, 48]	3.6 [−11, 87]	−6.4 [−26, 8.3]	6.3 [−12, 50]	3.9 [−3.0, 13]
IPW, drop both	22 [−10, 170]	11 [−3.4, 38]	3.7 [−8.3, 16]	10 unbounded	8.1** [0.2, 18]
No robust regression	13 [−58, 135]	−82 unbounded	50 [−21, 152]	10 [−33, 63]	7.7 [−22, 41]
Trim top 1%	15** [0.3, 77]	12 [−7.8, 118]	1.1 [−13, 17]	5.6 [−3.5, 18]	7.4** [0.8, 16]

Notes: Drop large purchases: respondents whose major purchases exceed 40 percent of planned outlays dropped. Drop interrupted: respondents who paused the survey dropped. IPW: survey weights multiplied by inverse probability weights. No robust regression: saving regression by weighted least squares without robustness weights. Trim top 1%: top 1 percent of saving rates dropped. Scaled difference $0.1 \times \beta_2 / \Delta\Phi$ (equation 4) in basis points of the saving rate (planned saving over net household income), with saving regression and first stage estimated on the same sample and with the same weights; survey weights in all specifications, multiplied by inverse probability weights where indicated. Pooled: $0.1 \times \sum_e w_e \beta_{2,e} / \sum_e w_e \Delta\Phi_e$ with inverse-variance weights. 90 percent Anderson–Rubin-type confidence sets in brackets, from 999 bootstrap draws that resample respondents within treatment arms and repeat the robust regression in each draw; “unbounded” when the first stage is too weak to bound the set. **, *: difference significantly positive at the 5 and 10 percent level in a one-sided bootstrap test.

Table A2: A realized disaster: responses in the closed and the open economy

	impact	1 year	2 years	5 years	10 years	20 years
<i>Closed economy, macro disaster</i>						
output (%)	-7.1	-10.9	-9.7	-6.7	-5.1	-3.3
consumption (%)	-6.4	-8.0	-7.7	-6.2	-4.5	-2.7
investment (%)	-9	-20	-16	-8	-7	-5
capital (%)	-0.4	-19.4	-22.0	-18.7	-14.7	-9.5
wage (%)	-4.0	-8.0	-7.0	-4.2	-3.8	-3.0
wealth Gini (points)	+1.0	+0.6	+0.4	-0.5	-2.0	-2.4
top 1% share (% change)	+2.9	+2.5	+2.2	+0.5	-3.0	-6.1
<i>Open economy, macro disaster</i>						
output (%)	-7.4	-8.8	-4.6	+0.8	+0.9	+0.3
consumption (%)	-2.9	-4.0	-4.0	-3.7	-2.9	-2.2
investment (%)	+48	+71	+50	+10	-1	0
capital (%)	-1.0	-13.3	-7.2	+3.1	+2.6	+0.8
wage (%)	-4.3	-5.8	-1.9	+3.3	+2.1	+0.6
wealth Gini (points)	+1.6	+1.5	+1.7	+0.9	-1.1	-2.3
top 1% share (% change)	+2.0	+1.0	+1.3	+0.2	-1.9	-4.3
<i>Open economy, concentrated disaster</i>						
output (%)	-0.4	-1.8	-0.7	+0.1	+0.1	0.0
consumption (%)	-2.8	-2.7	-2.5	-2.1	-1.6	-0.9
investment (%)	+82	+49	+20	+1	0	0
capital (%)	-1.1	-5.3	-1.9	+0.2	+0.3	+0.1
wealth Gini (points)	+2.0	+1.7	+1.5	+0.9	+0.3	-0.2
top 1% share (% change)	+2.9	+2.0	+2.0	+1.4	+0.6	-0.4

Notes: Generalized impulse responses: the path after a disaster minus the path without a disaster, both starting from the risky steady state at $p = 2\%$. Macro disaster: main calibration ($\gamma = 5$, $d = 0.6$). Concentrated disaster: $\gamma = 5$, $d = 0.8$, $D = 0.10$ on impact only. Three-year output loss: closed 10.2%, open 8.8%, concentrated 1.9%. Investment is relative to its no-disaster path; capital recovers whenever investment falls by less than capital. Top 1% share: percent change of the share relative to its no-disaster path (not percentage points); wealth Gini: difference in Gini points.

Table A3: Open economy: decomposition of the Gini response to $p : 1\% \rightarrow 2\%$ (Gini points)

step	range over calibrations	main calibration ($\gamma = 5$, $d = 0.6$)
partial equilibrium (prices and continuation fixed)	-0.05 to +0.23	+0.11
saving policies only	+0.34 to +0.62	+0.41
portfolio shares only	-0.56 to -0.17	-0.30
prices: lower domestic capital (r up, w down)	+0.32 to +0.65	+0.33
continuation re-solved at $p = 2\%$	-0.38 to -0.30	-0.31
general equilibrium	+0.12 to +0.25	+0.12

Notes: Open economy, macro disaster, $\gamma \in \{4.5, 5\}$ and $d \in [0.4, 0.8]$ (the calibrations with $\gamma = 5$ are in Table 3). Stationary distributions under the $p = 2\%$ policies, evaluated step by step from the $p = 1\%$ risky steady state. The price and continuation steps are averages over both orders. Domestic capital falls by 2.2 to 2.8%, the return rises by 16 to 20 basis points a year and the wage falls by 0.8 to 1.0%.

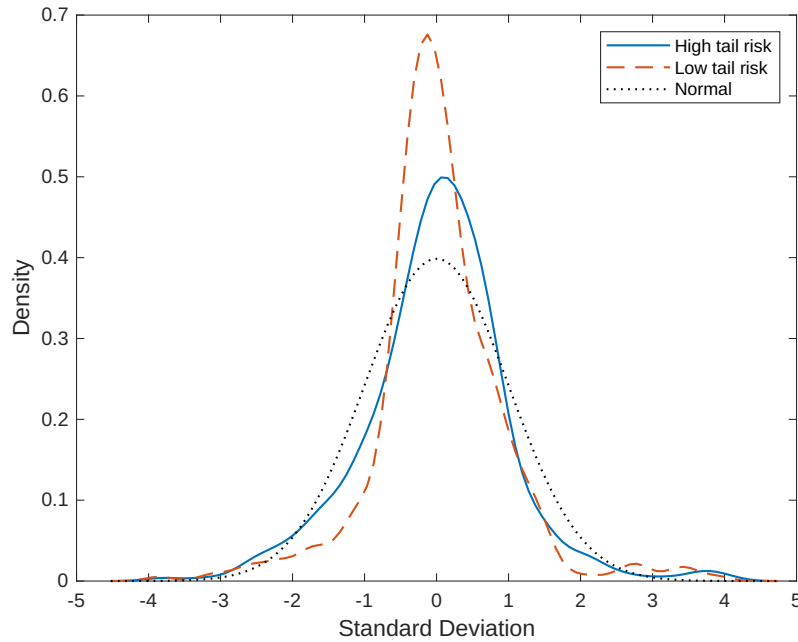


Figure A1: Estimated density from pooled standardized 3-year output growth distributions of countries in two groups: *High tail risk*: Argentina, Colombia, Peru, Venezuela (N=438). *Low tail risk*: Belgium, China, Netherlands, Taiwan (N=412). *Normal* is the standard normal density for comparison.

B Survey Appendix

This Appendix lists the most important survey questions from the Bundesbank Online Panel Households, Wave 32.

P3206 Stellen Sie sich vor, innerhalb der kommenden drei Jahre würde jeweils eines der folgenden Ereignisse eintreten. Was denken Sie, um wieviel Prozent wäre die Wirtschaftsleistung Deutschlands in diesem Fall jeweils geringer?

Hinweis: Bitte geben Sie an, um wieviel Prozent die Wirtschaftsleistung ein Jahr nach Eintritt des Ereignisses kleiner wäre als ohne Eintritt des Ereignisses. Wenn Sie einen Rückgang erwarten, geben Sie bitte einen Wert größer 0 ein. Wenn Sie keinen Rückgang erwarten, geben Sie bitte einen Wert von Null ein.

1. Finanzkrise
2. Pandemie mit neuem Erreger
3. Angriff Chinas auf Taiwan
4. Energiekrise

P3207 Was denken Sie, wie hoch ist die Wahrscheinlichkeit, dass das jeweilige Ereignis innerhalb der kommenden drei Jahre eintritt?

Hinweis: Bitte geben Sie jeweils Werte zwischen 0 und 100 ein. 100 bedeutet, dass das Ereignis Ihrer Einschätzung nach vollkommen sicher eintreten wird, 0, dass das

Ereignis vollkommen unmöglich ist.¹³

1. Finanzkrise
2. Pandemie mit neuem Erreger
3. Angriff Chinas auf Taiwan
4. Energiekrise

Treatment 1 and 2 – Financial crisis

T1: Die Banken sind seit der globalen Finanzkrise von 2008 deutlich widerstandsfähiger geworden. Die Kapitalpuffer, die entscheidend für die Widerstandsfähigkeit der Banken sind, stiegen seitdem um rund 50%. Banken können dadurch leichter durch wirtschaftlich herausfordernde Zeiten kommen, ohne gezwungen zu sein, die Kreditvergabe an Unternehmen und Haushalte einzuschränken.

T2: Überbewertete Vermögenswerte, beispielweise Immobilien, stellen eine Verwundbarkeit für das deutsche Finanzsystem dar. Der deutsche Aktienindex (DAX) hat seit Jahresbeginn rund 20 Prozent an Wert verloren. Schätzungen der Bundesbank zufolge sind Immobilienpreise in Deutschland rund 20-35 Prozent überbewertet. Sollten Immobilienpreise plötzlich fallen und zahlreiche Haushalte ihre Kredite nicht mehr bedienen können, drohen Banken erhebliche Verluste.

Treatment 3 and 4 – Pandemic

T3: Um zukünftige Pandemien effektiv zu verhindern oder abzuschwächen, wird mit Hochdruck an einer Reihe von Maßnahmen gearbeitet. Durch die mRNA-Technologie sollen wirksame Impfstoffe schnell verfügbar sein, wirksame Medikamente sollen schnell entwickelt werden können und das Infektionsgeschehen soll besser überwacht werden. Diese und weitere Maßnahmen können dazu beitragen, die Ausbreitung von Krankheitserregern zukünftig frühzeitig einzudämmen.

T4: Experten warnen, dass es jederzeit zu einer neuen Pandemie kommen könnte. So steht etwa die Haltung bestimmter Tierarten in China mit dem SARS-Virus 2002 in Verbindung, und im Mittleren Osten mit dem MERS-Ausbruch 2012. In Europa ist die Massentierhaltung eine potenzielle Brutstätte für neue Erreger. Aufgrund mangelnder Vorbereitung könnten die Folgen ebenso oder noch weitreichender als bei der Covid-19 Pandemie sein.

¹³The survey question is displayed to respondents in a way such that an info box linked to GDP ("Wirtschaftsleistung Deutschlands") is available, stating the following text: "Die Wirtschaftsleistung wird gewöhnlich durch das Bruttoinlandsprodukt (BIP) gemessen. Das BIP gibt den Gesamtwert aller Waren und Dienstleistungen an, die während eines Jahres innerhalb Deutschlands hergestellt wurden."

Treatment 5 and 6 – War between China and Taiwan

T5: Experten gehen davon aus, dass China derzeit nicht zu einer Invasion Taiwans bereit wäre. Im Falle einer möglichen zukünftigen Eskalation würden Bestrebungen in den USA und Europa, unabhängiger von Einfuhren aus Taiwan und China zu werden, die wirtschaftlichen Folgen begrenzen. Hierfür sollen Produktionsstätten in Europa und USA mit jeweils rund 40-50 Milliarden Euro gefördert werden.

T6: Hochrangige US-Militärs warnen, dass eine Invasion Chinas in Taiwan innerhalb der nächsten fünf Jahre droht. Da Taiwan zwei Drittel der weltweiten Halbleiter produziert, könnten die wirtschaftlichen Folgen in Deutschland und weltweit gravierend sein, beispielsweise für die Automobilproduktion. Die Rolle Chinas als Produktionsstandort und Absatzmarkt könnte im Falle von Spannungen zwischen China und den USA sowie möglicher Sanktionen gegenüber China die wirtschaftlichen Auswirkungen verstärken.

Treatment 7 and 8 – Energy supply crisis

T7: Die führenden deutschen Wirtschaftsforschungsinstitute erwarten im Falle eines sofortigen Gas-Lieferstopps Russlands keine Versorgungslücke beim Gas bis Ende 2023. Der Gasverbrauch deutscher Industrieunternehmen müsste dann nicht begrenzt werden. Die Versorgung privater Haushalte und sozialer Einrichtungen wäre ohnehin nicht gefährdet.

T8: Der Bundeswirtschaftsminister hat die zweite Krisenstufe im Notfallplan Gas ausgerufen. Grund dafür sei die seit Mitte Juni bestehende Kürzung der russischen Gaslieferungen sowie die hohen Preise am Gasmarkt. Eine Verdreifachung der Gaspreise für Haushalte und Unternehmen sei im Bereich des Möglichen, ebenso Einschränkungen in der Gasversorgung von Industrieunternehmen.

Control Group

T9: [No information]

P3210 *Sie sehen nun nochmal einige Dinge, für die man im Alltag Geld ausgeben kann oder muss. Wieviel planen Sie in den kommenden zwölf Monaten im Durchschnitt pro Monat für die folgenden Dinge jeweils auszugeben?*

- 1. größere Anschaffungen (z.B. Auto, Möbel, elektrische Geräte usw.)*
- 2. Wohnkosten (z.B. Miete, Hypothekenkredit, Nebenkosten)*
- 3. Sonstige Ausgaben (z.B. Einkäufe, Mobilität, Dienstleistungen, Reisen)*
- 4. Sparen (z.B. Sparkonto, Aktien, Anleihen)*

Depending on the treatment group, respondents are shown the next questions. The control group (T4) is asked about all four disaster types.

P3211 A-D *Wir möchten nun noch etwas mehr über Ihre Einschätzungen bezüglich der Auswirkungen und der Wahrscheinlichkeit möglicher Krisen erfahren. Es gibt hierbei kein richtig oder falsch, wir sind an Ihrer persönlichen Meinung interessiert. Stellen Sie sich vor, innerhalb der kommenden zwei Jahre würde eine [Finanzkrise/Pandemie mit neuem Erreger/ Angriff Chinas auf Taiwan/Energiekrise] eintreten. Was denken Sie, um wieviel Prozent wäre die Wirtschaftsleistung Deutschlands in diesem Fall geringer?*

P3213 A-D *Was denken Sie, wie hoch ist die Wahrscheinlichkeit, dass innerhalb der kommenden zwei Jahre eine [Finanzkrise/Pandemie mit neuem Erreger/ Angriff Chinas auf Taiwan/Energiekrise] eintritt?*

C Solution algorithm

This appendix describes how we solve the model of section 4. Subsections C.1.1 and C.1.2 describe the household problem with portfolio choice and the transition of the distribution. In the version of this algorithm in our earlier work, the disaster state was a recurrent stationary state with value function V^D . In the current model, V^D is replaced by the post-disaster continuation: the marginal value of wealth when a disaster strikes and the economy then recovers. Subsection C.2 describes how we compute the risky steady state together with this continuation, and subsection C.3 the Nonlinear DEGM Update (NDU) of Bayer et al. (2026), on which the exact post-disaster quarters rest.

C.1 The household problem with portfolio choice

In this subsection, we provide the solution algorithm for the Aiyagari model with disaster risk and portfolio choice. For simplicity, we abstract from the difference between workers and entrepreneurs introduced later in that section. There are three idiosyncratic state variables for each household: labor income productivity h , total asset holding a , and the *share* of wealth held in the local (risky) capital, q . We define two value functions that jointly characterize the optimization problem of the household: $V(a, q, h)$ is the value function of the household in “normal times”, while $V^D(a, q, h)$ is the value function of the household in the disaster state. They are

defined as follows:

$$\begin{aligned}
V(a, q, h) &= \max_{a', q'} \{u(R^p(q, 0)a + hw - a') + \\
&\quad \beta \mathbb{E} [(1 - p^D)V(a', q', h') + p^D V^D(a', q', h') \mid h]\}, \\
V^D(a, q, h) &= \max_{a', q'} \{u(R^p(q, \mu^D)a + hw - a') + \\
&\quad \beta \mathbb{E} [(1 - p^D)V(a', q', h') + p^D V^D(a', q', h') \mid h]\}, \\
a' &\geq 0, \quad q' \in [0, 1],
\end{aligned}$$

where p^D is the probability of a disaster, and μ^D is the size of the disaster, in terms of the size of depreciation of home capital. The return on the portfolio, $R^p(q, \mu)$, is defined as follows:

$$R^p(q, \mu) = (1 - q)R^f + q(R - \mu),$$

where $R = 1 - \delta + r$ as in the main text.

The two components of the solution algorithm are:

1. Solving the individual household problem for the optimal policy functions that determine optimal savings a^* given *gross capital income* $z := R^p(q, \mu)a$ and labor income hw , and the optimal portfolio choice q^* that is consistent with the optimal savings choice,
2. Solving the *distributional transition*, given the optimal policy of the households and the conditional distributions $F_a(a \mid h)$ and $F_{q|a}(q \mid a, h)$

The second step implies new equilibrium prices w and r . We solve for the stationary equilibrium by iterating on these two steps until convergence. For all what follows, we suppose a sufficiently dense grid for the three state variables, called $\mathcal{A}$, $\mathcal{Q}$, and $\mathcal{H}$, respectively, on which we solve the model.¹⁴

C.1.1 Endogenous gridpoint method with portfolio choice

For solving the individual household problem, we start with the baseline endogenous gridpoint method (Carroll, 2006) and adjust it for portfolio choice. For this, we use the insight that the household's optimal savings choice depends on future expectations and today's *cash on hand*, which is the sum of labor income and gross capital income, $hw + z$. The second insight is that optimal portfolio choice only depends on a first-order condition (and corner solutions) about *next* period's variables (in

¹⁴For the results in the main text, we use 100 grid points for wealth, 20 grid points for the portfolio share, and 10 grid points for labor productivity.

expectation); i.e., it is an intratemporal, not an intertemporal problem. We find the following first-order condition for q' :

$$\frac{\mathbb{E} [V_1^D(a', q', h')/R^p(q', \mu^D) \mid h]}{\mathbb{E} [V_1(a', q', h')/R^p(q', 0) \mid h]} = \frac{1 - p^D}{p^D} \frac{R - R^f}{R^f - (R - \mu^D)} =: \tau,$$

where V_1 (henceforth called *marginal value function*) denotes the derivative of value function V by its first argument, wealth, τ is a number depending on parameters and prices, while the left-hand side is increasing in q' , and depends on today's labor productivity h (which determines the expectation over h'). The corner solutions are the following: if the left-hand side is larger than threshold τ for $q' = 0$, the household would ideally like to short-sell the risky asset, but since this is not possible, she chooses $q' = 0$. If the left-hand side is smaller than τ for $q' = 1$, the household would like to additionally invest in the risky asset by borrowing in the foreign asset; since this is not possible, she holds all wealth in the risky asset, $q' = 1$. For any other case, there is an interior solution for q' . There, we take the lowest value on the grid $\mathcal{Q}$ where the left-hand side is larger or equal to τ as the optimal q' . In summary, we solve for optimal portfolio share q^* as a function of *future* optimal savings choices a' (on-grid) and today's labor productivity h (on-grid).

Next, we use $q^*(a', h)$ to generate the expectation of the future marginal value of a given savings choice, that enters the endogenous gridpoint method:

$$EV_1(a', h) := \mathbb{E} [(1 - p^D)V_1(a', q^*(a', h), h') + p^D V_1^D(a', q^*(a', h), h') \mid h].$$

The first order condition of the intertemporal consumption-savings problem gives that, for a given on-grid choice of a' , there is corresponding consumption choice $c^*(a', h)$ today. Then, using the budget constraint and the decomposition into different sources of income introduced above, we can solve for today's "optimally implied" gross capital income $z^*(a', h) = c^*(a', h) + a' - hw$, which we use as our "endogenous gridpoint". Next, we can apply (non-linear) interpolation to solve for the function $a^*(z, h)$, for which we know the interpolation nodes $z^*(\mathcal{A}, \mathcal{H})$ and $\mathcal{A}$. We account for the borrowing constraint $a' \geq 0$ as usual, by finding the threshold value $\bar{z}$ that maps to $a' = 0$ and set hand-to-mouth behavior for $z < \bar{z}$. The grid for gross capital income z is implied by the grids $\mathcal{A}$ and $\mathcal{Q}$ and asset returns, and depends on the disaster state μ . Hence, we can back out optimal savings $a^*(a, q, h)$ and $a^{*,D}(a, q, h)$ and correspondingly (using again the budget constraint) optimal consumption $c^*(a, q, h)$ and $c^{*,D}(a, q, h)$ for "normal times" as well as for the disaster state. Finally, we update the marginal value functions using the familiar envelope theorem, by which $V_1(a, q, h) = R^p(q, 0)u'(c^*(a, q, h))$ and $V_1^D(a, q, h) = R^p(q, \mu^D)u'(c^{*,D}(a, q, h))$. We iterate on this procedure until convergence of the marginal value functions.

C.1.2 Distributional transition

We build on the novel method of [Bayer et al. \(2026\)](#) for representing the continuous distributions and modelling their transition over time, which is more efficient and accurate than the histogram or “lottery”-method, which is standard in the literature. We iterate over the following two distributions: the distribution of total wealth a conditional on labor productivity h , $F_a(a | h)$, and the distribution of portfolio shares q conditional on wealth and labor productivity, $F_{q|a}(q | a, h)$. We start with an initial guess for these two distributions, which we update in each iteration.

The first step is to update the *end-of-period* distribution of wealth, $\tilde{F}_a(a' | h)$, which is the distribution of wealth after households have made their optimal savings and portfolio choice, but before the transition of labor productivity. The main insight is that we can use the distribution over optimal portfolio shares $F_{q|a}(q | a, h)$ to generate the distribution over gross capital income, z , in the following way:

$$F_z(z(\tilde{a}, q) | h) = F_a(a = 0 | h) + \int_{a>0} F_{q|a} \left(\frac{\tilde{a}/a(qR^e + R^f) - R^f}{R^e} | a, h \right) f_a(a | h) da,$$

if $R^e := R(\mu) - R^f$ is positive, and

$$F_z(z(\tilde{a}, q) | h) = F_a(a = 0 | h) + \int_{a>0} \left[1 - F_{q|a} \left(\frac{\tilde{a}/a(qR^e + R^f) - R^f}{R^e} | a, h \right) \right] f_a(a | h) da,$$

if R^e is negative (in the disaster state). Importantly, the policy function $a^*(z, h)$ is monotone in z . Therefore, we can then use the one-asset method of [Bayer et al. \(2026\)](#) to compute $\tilde{F}_a(a' | h)$, using $z(\mathcal{A}, \mathcal{Q})$ and $F_z(z(\mathcal{A}, \mathcal{Q} | h))$ as the (sorted) interpolation nodes.

The second step is to update the end-of-period distribution of portfolio shares, $\tilde{F}_{q|a}(q' | a', h)$. Note that this is the distribution over next period’s portfolio shares, conditioning on *next period’s* optimal wealth level a' . Building this distribution is straightforward, as it is just a step function that jumps at the optimal portfolio share $q^*(a', h)$:

$$\tilde{F}_{q|a}(q' | a', h) = \begin{cases} 0, & q' < q^*(a', h) \\ 1, & q' \geq q^*(a', h) \end{cases}$$

This demonstrates the advantage of representing the problem in terms of conditional cumulative distribution functions when iterating forward distributions that follow from optimal portfolio choices.

Finally, we build next period’s distributions F_a and $F_{q|a}$ from end-of-period distributions $\tilde{F}_a$ and $\tilde{F}_{q|a}$, by integrating over the transition of labor productivity h ,

using a finite quadrature-procedure that implies a Markov-chain with a transition matrix. The distribution F_h is constant and given as the stationary distribution of the Markov chain (as an extension, it could possibly depend on aggregate states, i.e. the disaster state).

C.2 The risky steady state with a post-disaster continuation

We compute the risky steady state of section 4: the stationary distribution of an economy in which households anticipate a disaster with probability $p/4$ each quarter, but in which no disaster occurs. The difficulty is the continuation. A stationary disaster state, as in the algorithm above, treats the disaster as a recurrent state of the household problem; it cannot represent a disaster whose effects—scarce capital, a high return, a low wage, depressed productivity and profits—unfold over years and depend on the distribution of wealth on which the disaster strikes. Following [Bigio and Sannikov \(2021\)](#), we instead let households anticipate that, if a disaster strikes, the economy is hit once and then follows a deterministic recovery path back to its deterministic steady state. The risky steady state is then a fixed point between the pre-disaster distribution and the continuation value implied by the recovery from that distribution.¹⁵

Objects. Let $\mathcal{M}^{RSS}$ denote the model with disaster probability $p > 0$ and $\mathcal{M}^{DSS}$ a copy with $p = 0$. We solve the deterministic steady state of $\mathcal{M}^{DSS}$ once and linearize the model around it with the perturbation method of [Bayer and Luetticke \(2020\)](#), which treats the (compressed) distribution as a state. This yields a first-order rule $x_{t+1} = h_x x_t$, $y_t = g_x x_t$ for the deviations x_t of the states, including the distribution, and y_t of the controls, including the marginal value function $V_{m,t}(m, h)$, from the deterministic steady state. Since the post-disaster economy is the deterministic one, the residual function that is differentiated vanishes at the deterministic steady state and carries no disaster branch; disaster risk enters the risky steady state only through the continuation.

The continuation is the marginal value of a unit of wealth carried into the disaster quarter,

$$V_m^D(m, h) = \sum_j \pi_j (R^D - \ell_j) u'(c_j^D(m, h)),$$

which enters the Euler equation (17) with weight $p/4$. It depends on the pre-disaster distribution F through the prices of the disaster quarter and through the recovery

¹⁵The construction is closely related to the risky steady state of [Coeurdacier et al. \(2011\)](#): the economy without realized shocks, but with the shocks' risk priced. It differs in that the disaster branch is not perturbed jointly with the aggregate states; its continuation value is computed from the deterministic economy's recovery path.

path. We write $V_m^D = \mathcal{T}(F)$ for this *continuation map*.

The continuation map. Given a candidate pre-disaster distribution F :

1. Households start the disaster quarter from F , which already contains their precautionary saving. Capital is destroyed, household i loses $\ell_j \in \{0, d\}$ of its wealth with probabilities π_j , and the other disaster components (TFP, profit squeeze) take their impact values. Aggregates and prices of the quarter follow from F .
2. Households choose consumption in the disaster quarter against the marginal value of the following quarter. The resulting distribution is moved forward exactly over the first K quarters of the recovery with the NDU of subsection C.3, and at quarter $K+1$ it is handed to the first-order rule as the initial state of the recovery.
3. The disaster-quarter policies give $c_j^D(m, h)$ and hence $V_m^D = \mathcal{T}(F)$.

The disaster itself is never extrapolated by the linear rule: a jump in depreciation of the size of a disaster, fed into the first-order rule as a shock, produces explosive marginal values. It enters only through the exact disaster quarter and the exact window, and what the linear rule receives is the distribution the disaster leaves behind.

The fixed point. We solve for the risky steady state and the continuation jointly, inside the root search for the market-clearing capital stock. Each evaluation of excess capital supply

1. solves the household problem with the current continuation V_m^D held fixed (subsection C.1.1, with the Euler equation (17)) and the stationary distribution F^{RSS} (subsection C.1.2);
2. evaluates the continuation map at that distribution, $\hat{V}_m^D = \mathcal{T}(F^{RSS})$;
3. updates the continuation in logs with damping ω , $\log V_m^{D, \text{new}} = (1-\omega) \log V_m^D + \omega \log \hat{V}_m^D$.

The continuation thus converges together with the capital stock rather than in an outer loop. Because the number of updates is tied to the number of evaluations the root search happens to need, we finish with a polish step: we iterate the continuation to convergence at the returned prices, re-solve the capital market once with the continuation held fixed, and repeat at most three times. A solution is accepted if (i) the capital market clears, (ii) the distribution is a valid cumulative distribution

function with unit mass, and (iii) the continuation residual $\max|\log \mathcal{T}(F^{RSS}) - \log V_m^D|$ at the returned point is below tolerance. At $p = 0$ the continuation has no effect on the solution and only (i) and (ii) apply.

Partial equilibrium. The saving responses of section 5 hold prices at the risky steady state with $p = 1\%$, raise p to 2% in the Euler equation, and re-solve the continuation map at the resulting distribution. The general-equilibrium response solves both risky steady states in full.

Open economy. In the open economy, the household problem is that of subsection C.1.1, with the fund’s return in place of the foreign return, and the fund’s foreign share is an additional unknown, updated by a price-adjustment rule toward the no-arbitrage condition of the fund’s holders. The fund’s foreign position is an aggregate state of the recovery, which lets the economy repatriate foreign assets after a disaster.

C.3 The nonlinear DEGM update (NDU)

A disaster displaces the distribution far from the deterministic steady state, where a first-order rule is least accurate. The NDU computes the first K quarters after the disaster with an exact, nonlinear law of motion for the distribution, while household policies remain first order; at quarter $K + 1$ the exact distribution is handed to the linear rule. The NDU is the method of Bayer et al. (2026), developed there for large transfers: it moves the wealth distribution nonlinearly within a short window while the aggregate economy is solved with a first-order state-space approximation. It builds on the DEGM of Bayer et al. (2026). We apply it to the disaster and its recovery. Two representations make it work.

Policies as maps from cash on hand. From the linear rule we obtain next quarter’s marginal value $V_{m,t+1}$ at the predicted state. On each grid point m_j of next quarter’s wealth, the Euler equation gives

$$\tilde{c}_t(m_j, h) = (u')^{-1}(\beta \mathbb{E}_t[V_{m,t+1}(m_j, h') \mid h]), \quad z_t^*(m_j, h) = \tilde{c}_t(m_j, h) + m_j :$$

a household with cash on hand $z_t^*(m_j, h)$ chooses exactly $m' = m_j$. In the one-asset model, this map contains neither income nor prices; it depends only on the continuation and β . Indexing the policy by cash on hand rather than by current wealth is essential after a disaster: a policy indexed by wealth implicitly carries the steady-state income attached to each grid point, and the disaster’s first effect is on exactly that income. Indexed by cash on hand, the disaster relocates households along a map that is itself unchanged, and the budget constraint holds by construction.

The transition reads the distribution at pre-images. Cash on hand is affine in wealth, $z_t(m, h) = R_t m + w_t h + \text{other income}$, so each node's pre-image is exact,

$$m_t^{\text{pre}}(m_j, h) = \frac{z_t^*(m_j, h) - w_t h - \text{other income}}{R_t},$$

and since $m' \leq m_j$ if and only if $m \leq m_t^{\text{pre}}(m_j, h)$,

$$F_{t+1}(m_j | h') = \sum_h \Pi(h, h') \frac{\varsigma_h}{\varsigma_{h'}} F_t(m_t^{\text{pre}}(m_j, h) | h),$$

with Π the productivity transition and ς_h the stationary productivity shares. The only object that is interpolated is the cumulative distribution F_t , which is smooth and monotone; the policy is never projected onto the fixed grid. The borrowing constraint needs no special treatment: it is the first node, and $F_t(m_t^{\text{pre}}(m_1, h))$ is the mass at the constraint. At the top of the grid we cap the transition at the column's mass. Household-specific disaster losses enter in the disaster quarter through the pre-images of each loss node ℓ_j , weighted by π_j .

We use the same backward transition in the stationary solve and in the linearized model, so that the deterministic steady state is a fixed point of the operator that the window iterates; a forward and a backward discretization of the same operator differ on a finite grid, and mixing them would make the window drift without any shock.

The window. Within the window, aggregate capital is predetermined by the incoming distribution, so prices are predetermined and each quarter is a forward recursion without a root search: read the marginal value from the linear rule at the predicted state, build the cash-on-hand map, move the distribution with the exact transition, aggregate. In the disaster quarter, we build the policy from the continuation at the predicted next-quarter state; re-evaluating it at the realized next-quarter distribution and iterating to a fixed point changes next-quarter capital by 0.003 percent. We use $K = 1$ exact quarter for the local disaster, which has no persistent components, and $K = 16$ quarters for the macro disaster, whose persistent destruction, productivity loss and profit squeeze move the distribution further. The window's fixed point converges to residuals below 10^{-10} in five to seven iterations.

Impulse responses. The responses to a realized disaster in section 5 are generalized impulse responses: the path after a disaster minus the path without one, both starting from the risky steady state and both computed with the same window and the same linear continuation. Without a disaster the economy also drifts from the risky to the deterministic steady state, because the continuation economy expects

no further disasters; taking the difference removes that drift.

D Derivations for section 3

D.1 Proof of Proposition 1

Holding k fixed, $c_N = \bar{c}$ and $c_D - \bar{c} = -Dk$ exactly. Taylor expansion of marginal utility around $\bar{c}$ therefore gives

$$\begin{aligned} u'(c_D) &= u'(\bar{c}) + u''(\bar{c})(c_D - \bar{c}) + O((c_D - \bar{c})^2) \\ &= u'(\bar{c}) - u''(\bar{c})Dk + O(D^2), \end{aligned} \quad (\text{D.1})$$

$$u'(c_D) - u'(c_N) = -u''(\bar{c})Dk + O(D^2), \quad (\text{D.2})$$

where the last line subtracts $u'(c_N) = u'(\bar{c})$. Substituting these two Taylor expansions separately into (8) yields

$$\begin{aligned} \left. \frac{\partial}{\partial q} \mathbb{E}[Ru'(c_1)] \right|_{q=0} &= R_0 [-u''(\bar{c})Dk + O(D^2)] - D [u'(\bar{c}) - u''(\bar{c})Dk + O(D^2)] \\ &= D [-R_0 k u''(\bar{c}) - u'(\bar{c})] + \underbrace{D^2 k u''(\bar{c}) + O(D^2) + O(D^3)}_{=O(D^2)} \\ &= D u'(\bar{c}) \left[-\frac{R_0 k u''(\bar{c})}{u'(\bar{c})} - 1 \right] + O(D^2) \end{aligned} \quad (\text{D.3})$$

$$= D u'(\bar{c})(\gamma\lambda - 1) + O(D^2). \quad (\text{D.4})$$

The final equality uses $-\bar{c}u''(\bar{c})/u'(\bar{c}) = \gamma$ and, by (9) at $\psi = k$, $R_0 k/\bar{c} = \lambda$. Let $F(k, q)$ denote the left-hand side of (6). At $q = 0$,

$$F_k(k, 0) = u''(a - k) + \beta R_0^2 u''(\bar{c}) < 0. \quad (\text{D.5})$$

The implicit-function theorem implies for the first-order condition (6) that $dk^*/dq = -F_q/F_k$, whose sign therefore equals that of F_q and hence, by (D.4), that of $\gamma\lambda - 1$ to leading order in D . Since $a > 0$, the saving rate k^*/a has the same sign response.

D.2 The expected-return channel

We follow the seminal approach of Arrow and Pratt in computing changes in the savings response that are caused by a marginal increase in asset return risk, starting from the deterministic case. To this end, we perturb equation (6) with respect to deviations in return risk R .

At first order, $R = R_0 + \epsilon$, where R_0 describes the steady state gross return. A first-order Taylor expansion of the expectation in (6) around R_0 gives

$$\mathbb{E}[Ru'(Rk + y)] \approx \mathbb{E}[R_0 u'(R_0 k + y) + (u'(R_0 k + y) + R_0 u''(R_0 k + y)k)\epsilon] \quad (\text{D.6})$$

As $\mathbb{E}[\epsilon] = 0$, this has the well-known implication that up to first order, risk does not have an impact. As certainty equivalence holds, the household is on the Euler equation under deterministic returns:

$$R_0 = \frac{u'(a - k)}{\beta u'(R_0 k + y)} \quad (\text{D.7})$$

Assuming CRRA preferences, $u'(c) = c^{-\gamma}$, the optimal saving rate (out of total funds available) k/a equals

$$\frac{k^*}{a} = \frac{(\beta R_0)^{1/\gamma} - y/a}{R_0 + (\beta R_0)^{1/\gamma}} \quad (\text{D.8})$$

We can analyze the response of the optimal saving rate to changes in the (ergodic) steady state return R_0 . Barring off-setting general equilibrium effects, a higher risk of capital destruction lowers the expected return on savings. Taking the first derivative of the optimal saving rate by R_0 yields

$$\frac{\partial k^*/a}{\partial R_0} = \mathcal{C} + (1 - \theta_0) \frac{1 + \beta^{1/\gamma} R_0^{1/\gamma - 1} / \gamma}{(R_0 + (\beta R_0)^{1/\gamma})^2} \quad (\text{D.9})$$

where $\mathcal{C}$ collects terms independent of idiosyncratic variables, and $\theta_0 := \frac{k_0}{a}$ is the share of all available funds, including labor income, that the household commits to capital, and hence a measure of idiosyncratic (ex-ante) wealth. It shows that poorer, more labor income-dependent households react more strongly to changes in expected returns.¹⁶

To fix ideas, compare two households with high (y_h) and low (y_l) labor income. For illustrative purposes, we consider the case where both households have the same expected resources in the second period, for a given asset return R , which implies that the household with lower labor income has more initial resources: $a(y_l) > a(y_h)$, as well as $\theta_0(y_l) > \theta_0(y_h)$. Consider the two-period intertemporal consumption-savings problem for the household with low labor income. While consumption in period one, denoted by C_0 , is the same for both types of households by assumption, the household who is more capital income-dependent saves more, both in absolute and in relative terms. Therefore, once the expected saving return falls, the negative income effect is much more severe for the asset-rich household—as illustrated by the blue budget line moving further towards the zero point than the red budget line—they reduce their consumption in the first period.

Now consider the effect of a decline in the ex-ante return on savings, $R' < R$,

¹⁶This heterogeneity in “reaching for yield” is a common model prediction in the literature that accounts for heterogeneity in the composition of income, and has found some empirical success (Gomes et al., 2025).

on the saving of more labor income-dependent households. Due to the substitution effect—the less negative slope of the budget constraint line—dominating for this household-type, saving falls.

Importantly, this first-order analysis already reveals that, if heightened risk of capital destruction lowers the expected returns on savings, wealth inequality increases, as poorer households will respond with a relatively low saving rate (whether the response is negative or positive depends on constant $\mathcal{C}$. See below for the quantitative assessment of the heterogeneous saving responses in the two-period model).

D.3 Fixed-mean higher-moment corrections

At second order, $R = R_0 + \epsilon + \frac{1}{2}\epsilon^2$, a second-order Taylor expansion adds the following terms to the expectation-term in (D.6):

$$\mathbb{E} \left[\frac{\epsilon^2}{2} \{2ku''(R_0k + y) + R_0k^2u'''(R_0k + y)\} \right] \quad (\text{D.10})$$

Defining return variance $\sigma^2 = \mathbb{E}[\epsilon^2]$, rearranging adds the following term to the left-hand side of (D.7):

$$\frac{\gamma\sigma^2\lambda}{2R_0}(\rho\lambda - 2) \quad (\text{D.11})$$

where we define $\rho := -c \frac{u'''(c)}{u''(c)}$ as the coefficient of relative *prudence*, and λ is the exposure measure of (9), here equal to the gross asset-income share (10). The richer the household is (in expectation), the higher is λ , which is bounded above by 1. Hence, for a low value of prudence, $\rho \leq 2$, where $\rho = 2$ is the case if $\gamma = 1$ (log-preferences), the term (D.11) becomes negative, causing the household to save *less* than without accounting for risk.

This finding is not new, see Angeletos (2007). At a fixed mean, our analysis adds an inequality dimension to it: heterogeneity in wealth levels implies heterogeneous values of λ . For a common prudence level $\rho > 2$, the variance correction is negative for households with $\lambda < 2/\rho$ and positive for those with $\lambda > 2/\rho$.

Finally, we extend the analysis of risk to the third order. This allows us to analyze the effect of investment risk with a skewed distribution. At third order, $R = R_0 + \epsilon + \frac{1}{2}\epsilon^2 + \frac{1}{6}\epsilon^3$, a third-order Taylor expansion adds the following terms to the expectation-term in (D.6):

$$\mathbb{E} \left[\frac{\epsilon^3}{6} (3k^2u'''(Rk + y) + Rk^3u^{IV}(Rk + y)) \right] \quad (\text{D.12})$$

Defining skewness $\varsigma = E[\epsilon^3]/\sigma^3$, we find that accounting for third order risk adds

an additional term to the left-hand side of Euler equation (D.7):

$$\frac{\gamma \rho \varsigma \sigma^3 \lambda^2}{6 R_0^2} (3 - \kappa \lambda) \quad (\text{D.13})$$

where we define $\kappa := -c \frac{u^{IV}(c)}{u'''(c)}$ as the coefficient of relative *temperance*. It holds that $\kappa = \gamma + 2$. For temperance above 3, we thus find heterogeneity in the sign of the savings response to skewness: poorer households with $\lambda < 3/\kappa$ save less when returns become more negatively skewed, $\varsigma < 0$, while richer households with $\lambda > 3/\kappa$ save more in that case. This fixed-mean higher-moment calculation yields the following auxiliary result: Holding the mean return fixed, under CRRA preferences with a common coefficient of relative risk aversion γ and heterogeneity in λ , there are thus thresholds $\underline{\lambda} \leq \bar{\lambda} < 1$ such that skewed return risk affects saving rates negatively for $\lambda < \underline{\lambda}$ and positively for $\lambda > \bar{\lambda}$, if and only if $\gamma > 1$.

The two higher-moment terms inherit the reading of (9) along with the first-order one. In the expansions above, k appears only as the sensitivity of second-period consumption to the return deviation at the deterministic point, $\partial c_1 / \partial \epsilon|_{\epsilon=0} = k$, which in the two-period problem is the same object as the destruction exposure ψ up to sign, since $R = R_0 - D$ in the disaster state. Wherever the exposure differs from the principal, (D.11) and (D.13) therefore hold with λ read off (9), and the cutoffs $2/\rho$ and $3/\kappa$ are unaffected.

D.4 The continuation: derivation

Let a destruction of fraction D lower the wage by αD under the production function $W = (1 - \alpha)(N/K)^{-\alpha}$. Consistent with the two-period timing, the wage in the disaster period is paid from production with the full capital stock; the wage shortfall begins in the first post-disaster period. Let a fraction $\phi \in [0, 1)$ of the aggregate shortfall persist from one period to the next, $D_t = D\phi^t$ for $t \geq 1$, and let $R_d > R_0$ be the post-disaster gross return. Thus $\phi = 0$ is immediate aggregate recovery, with no wage loss. Discounted labor income is

$$Y^N := W + \sum_{t=1}^{\infty} R_d^{-t} (1 - \alpha D \phi^t) W = W \left(\frac{R_d}{R_d - 1} - \alpha D \sum_{t=1}^{\infty} \left(\frac{\phi}{R_d} \right)^t \right) \quad (\text{D.14})$$

$$= W \left(\frac{R_d}{R_d - 1} - \alpha \frac{D\phi}{R_d - \phi} \right) \quad (\text{D.15})$$

The household's capital shortfall recovers at rate $\chi \in [0, 1]$, so $k_t = (1 - D\chi^t)k$. The two persistences govern distinct objects: ϕ determines the wage path, while χ

determines the household's own wealth-recovery. Discounted net capital income is

$$Y^K := \sum_{t=0}^{\infty} R_d^{-t} (R_d - 1) k_t = (R_d - 1) k \sum_{t=0}^{\infty} R_d^{-t} (1 - D \chi^t) \quad (\text{D.16})$$

$$= (R_d - 1) k \left(\frac{R_d}{R_d - 1} - D \sum_{t=0}^{\infty} \left(\frac{\chi}{R_d} \right)^t \right) \quad (\text{D.17})$$

$$= (R_d - 1) k \left(\frac{R_d}{R_d - 1} - \frac{D R_d}{R_d - \chi} \right) \quad (\text{D.18})$$

Here capital contributes its *net* income flow $(R_d - 1)k_t$, not its cum-dividend position: repeatedly discounting principal would double-count it. The terminal two-period problem is the exception, which is why its exposure equals the principal in (10).

Assuming that the permanent income hypothesis holds for the long-run future, the period consumption out of total future lifetime income is then given by

$$\frac{R_d - 1}{R_d} (Y^N + Y^K) = W R^N(D) + (R_d - 1) k R^K(D) \quad (\text{D.19})$$

where $R^N(D) := 1 - \alpha \frac{\phi D (R_d - 1)}{R_d (R_d - \phi)} < 1$ if $D > 0$ and $\phi > 0$, and

$$R^K(D) := 1 - \frac{(R_d - 1) D}{R_d - \chi} = 1 - v D, \quad v := \frac{R_d - 1}{R_d - \chi} \leq 1. \quad (\text{D.20})$$

For further tractability, we abstract from the effect of D on R_d and linearize $R^N(D)$ around $D = 0$:

$$R^N(D) \approx 1 - \alpha \frac{\phi (R_d - 1)}{R_d (R_d - \phi)} D = \frac{1}{R_d} \left(R_d - D \alpha \frac{\phi (R_d - 1)}{R_d - \phi} \right) \quad (\text{D.21})$$

Under that same abstraction $R^K(D)$ is already exactly linear in D and needs no expansion. The deterministic point is now the annuitised consumption level at $D = 0$, which is the wage plus the net return on the household's capital. It plays the role $\bar{c}$ played in the two-period problem, and we keep the notation: $\bar{c} = W + (R_0 - 1)k$. The first-order exposure of annuitised lifetime consumption to the destruction share D is then $W R^N(D) + (R_d - 1) k R^K(D) \approx \bar{c} - \psi D$, with the human-wealth and asset-wealth components ψ^N and ψ^K of (12). Because ψ is a flow, its natural benchmark is the flow share of asset income $\tilde{s}$ rather than the gross share (10): principal belongs to the terminal two-period problem, not to an infinite-horizon income flow. Replacing the two-period principal k by ψ gives (13).

When the two persistences do coincide, (13) collapses to a form in which its struc-

ture can be read off directly. We record this case because it makes the mechanism legible.

Lemma 1. *Suppose $\chi = \phi$, and write $g := (R_d - 1)/(R_d - \phi)$ for the common decay factor, so that $v = g$. Retaining the abstraction from the effect of D on R_d made above, so that $R_0/R_d \approx 1$, the wage exposure satisfies $R_0\psi^N/\bar{c} = \alpha\phi g(1 - \tilde{s})$, and (13) becomes*

$$\lambda = g(\alpha\phi + (1 - \alpha\phi)\tilde{s}). \quad (\text{D.22})$$

The exposure measure is then an affine and increasing function of the flow share, with floor $\alpha\phi g$, attained by households with no asset income, and slope $(1 - \alpha\phi)g < 1$.

Equation (D.22) shows that recovery compresses cross-sectional exposure: the wage channel creates a floor, while the asset channel attenuates its slope. The same qualitative logic holds when the persistences differ.

Proof of Proposition 2. Since $v = (R_d - 1)/(R_d - \chi)$ is increasing in χ , so is λ in (13). In the long-run Euler equation, the return loss in (8) remains D per unit of capital, but marginal utility is evaluated at annuitized continuation consumption. By (12),

$$\bar{c}_D = \bar{c} - \psi D + O(D^2), \quad \bar{c}_N = \bar{c}. \quad (\text{D.23})$$

Hence $u'(\bar{c}_D) - u'(\bar{c}_N) = -u''(\bar{c})\psi D + O(D^2)$. Substitution into (8) gives

$$\begin{aligned} \left. \frac{\partial}{\partial q} \mathbb{E}[Ru'(c_1)] \right|_{q=0} &= D u'(\bar{c}) \left[-\frac{R_0\psi u''(\bar{c})}{u'(\bar{c})} - 1 \right] + O(D^2) \\ &= D u'(\bar{c})(\gamma\lambda - 1) + O(D^2), \end{aligned} \quad (\text{D.24})$$

The sign changes at $\lambda = 1/\gamma$. Monotonicity in χ then gives (i)–(iii).

The higher-moment terms (D.11) and (D.13) also carry over unchanged, evaluated at λ of the infinite horizon. Under the two-parameter disaster distribution they are higher-order corrections to the leading mean channel, where the first-order cutoff remains $1/\gamma$.

D.5 Disasters that also lower productivity

So far a disaster destroys capital and nothing else. Historical disasters also lower productivity, and the macro-disaster literature typically lets the two fall together (Gourio, 2012). This subsection extends the long-run analysis by a TFP loss at the disaster. Notation is as in subsection 3.2 and Appendix D.4.

Setup. Production is Hicks-neutral, $Y = ZK^\alpha N^{1-\alpha}$, with N fixed. The household's capital path is unchanged, $k_t = (1 - D\chi^t)k$. For $t \geq 1$ the aggregate economy carries a capital shortfall $K_t = K(1 - D_t)$ and a TFP shortfall $Z_t = Z(1 - \omega_t)$. As for the wage above, production in the disaster period uses the pre-disaster K and Z . Under this timing the disaster-period term $-D u'(c_D)$ in (8) is unchanged, so TFP enters *only* through λ and the cutoff stays $1/\gamma$. To first order, factor prices move by

$$\hat{w}_t = -(\omega_t + \alpha D_t), \quad \Delta(R_t - 1) = r^k(-\omega_t + (1 - \alpha)D_t), \quad (\text{D.25})$$

where $r^k = R_0 - 1 + \delta$ is the rental rate. Write $\mathcal{A}[x] := \frac{R-1}{R} \sum_{t \geq 1} R^{-t} x_t$ for the annuity operator implicit in ψ^N , so that $a(\phi) := \mathcal{A}[\phi^t] = \frac{(R-1)\phi}{R(R-\phi)}$ and $\psi^N = \alpha W a(\phi)$.

Level and gap. Reparametrise the aggregate state into a *level* $\omega_t/(1 - \alpha)$, the proportional size by which the economy shrinks once capital has adjusted to the new productivity, and a *gap*

$$x_t := \frac{\omega_t}{1 - \alpha} - D_t, \quad (\text{D.26})$$

capital relative to productivity. A negative gap means scarce capital and a high return; a positive gap means capital is over-abundant relative to productivity, and the return is low. Since $\omega_t + \alpha D_t = \omega_t/(1 - \alpha) - \alpha x_t$ and $-\omega_t + (1 - \alpha)D_t = -(1 - \alpha)x_t$, the exposure (13) becomes

$$\frac{\lambda}{R_0} = \underbrace{v \tilde{s}}_{\text{own capital}} + \underbrace{(1 - \tilde{s}) \frac{\mathcal{A}[\omega/(1 - \alpha)] - \alpha \mathcal{A}[x]}{D}}_{\text{wage: level minus gap}} + \underbrace{m \tilde{s} (1 - \alpha) \frac{\mathcal{A}[x]}{D}}_{\text{return: gap only}}, \quad (\text{D.27})$$

with $m := r^k/(R_0 - 1) = 1 + \delta/(R_0 - 1)$, again with $R_0/R_d \approx 1$; the wedge between firm and household returns cancels from m . Three readings follow.

1. *TFP is an aggregate-recovery object.* It never enters through χ : only the own-capital term carries individual recovery. TFP moves the two aggregate terms, which recover at different speeds. The level recovers at the TFP persistence ϕ_Z ($\phi_Z = 1$ if permanent). The gap recovers at the rebuilding rate ϕ , measured against the *new* capital target.
2. *Capital owners are exposed to the gap, not the level.* A permanent TFP loss also lowers the capital target; once capital has adjusted, the return is back at R_0 . Only the transitional gap moves the return.
3. *Leverage.* TFP hits the gross rental rate, but households earn the net return, so net capital income is a levered claim with $m - 1 = \delta/(R_0 - 1)$. Since

depreciation is large relative to the net return, m is well above one: a positive gap lowers capital income proportionally several times more than wages.

In the two-factor form of (13), $\lambda = v_{\text{eff}}\tilde{s} + R_0\psi_{\text{eff}}^N/\bar{c}$ with $v_{\text{eff}} = v + m(1 - \alpha)\mathcal{A}[x]/D$ and ψ_{eff}^N the level loss minus α times the gap. Destruction alone gives $x_t = -D\phi^t$: a scarcity hedge for capital and a wage loss, the case of subsection 3.2. TFP removes or reverses the hedge, which raises the effective χ toward the persistence of the capital shortfall. When $m(1 - \alpha)\mathcal{A}[x]/D$ is large, $v_{\text{eff}} > 1$: exposure then exceeds the open-economy corner $\lambda = \tilde{s}$ and cannot be written as any $\chi \in [0, 1]$.

Table D1: Exposure under TFP disasters, special cases

case	ω_t	gap x_t	λ
destruction only, closed	0	$-D\phi^t$	$R_0[v\tilde{s} + (1 - \tilde{s})\alpha a(\phi) - m(1 - \alpha)\tilde{s}a(\phi)]$
open economy	0	$-(R \text{ pinned})$	$\tilde{s}$
open economy + TFP	ω_t	$-(R \text{ pinned})$	$\tilde{s} + R_0(1 - \tilde{s})\mathcal{A}[\frac{\omega}{1 - \alpha}]/D$ (compresses)
balanced, permanent	$(1 - \alpha)D$	0	$R_0[\tilde{s} + (1 - \tilde{s})/R] \approx 1$
permanent, τ_p of balanced	$\tau_p(1 - \alpha)D$	$-(1 - \tau_p)D\phi^t$	gap shrinks, never positive
persistent AR(1)	$\tau_s(1 - \alpha)D\phi_Z^t$	$\tau_s D\phi_Z^t - D\phi^t$	$+\tau_s(1 - \alpha)R_0a(\phi_Z)[1 + (m - 1)\tilde{s}]$ (steepens)

Table D1 collects the special cases. The balanced permanent case nests the representative-agent result as a corollary.

Proposition 3 (Gourio as a special case). *Suppose the disaster lowers TFP permanently in proportion to the capital loss, $\omega_t = (1 - \alpha)D$, and $\chi = 1$. Then prices never move, every household loses the same fraction D of its income, and $\lambda \approx 1$ for all households. The condition $\gamma\lambda > 1$ reduces to $\gamma > 1$: higher disaster risk raises saving if and only if the IES is below one.*

This is Gourio's (2012) result that investment falls with disaster risk iff the IES exceeds one; the threshold $1/\gamma$ is its heterogeneous-exposure generalisation. Between a destruction-only economy in which $\lambda_i < 1/\gamma$ for every household and the balanced case, where $\lambda_i \approx 1$ for all, lies a window of TFP intensities that splits the distribution. Let $\lambda_i(\tau) = \lambda_i^D + \tau\Delta_i$, where τ scales the size of the TFP loss relative to the balanced case, $\omega_t = \tau(1 - \alpha)D$ times its recovery path, so that τ equals Gourio's ratio b_{tfp}/b_k in labor-augmenting units.

Proposition 4 (TFP window, sketch). *Suppose the TFP increment Δ_i increases in $\tilde{s}_i$, as it does for a transitory loss, or for a mixture with a large enough transitory share. Then there is an interval $(\tau_{\text{top}}, \tau_{\text{bottom}})$ in which the most exposed households raise saving and the rest lower it. Below it every household lowers saving; above it every household raises saving, as in Proposition 3. The cutoff share $\tilde{s}^*(\tau)$ falls monotonically through the distribution.*

Which disasters steepen exposure. TFP raises the exposure of the rich relative to the poor only through a positive gap: the disaster must leave capital overabundant relative to productivity for a while. That happens when TFP falls faster or deeper than the capital stock, and in the transitory component that later recovers. A permanent TFP loss is mainly a wage shock; on its own it raises the exposure of the poor more than that of the rich, and helps the top only by removing their scarcity hedge.

The baseline is a *persistent* loss, $\phi_Z < 1$, consistent with stationary TFP in the full model; the permanent case $\phi_Z = 1$ is the unit-root limit of Barro (2006), Gourio (2012) and the permanent component of Nakamura et al. (2013), and is kept because it delivers $x = 0$ and Proposition 3. What matters is not permanence as such but whether capital has time to adjust: as $\phi_Z \rightarrow \phi$ from below, investment falls during the low-TFP spell, D_t rises endogenously and the gap shrinks toward its permanent-case value. Increments computed with $D_t = D\phi^t$ held fixed therefore overstate the gap, increasingly so as ϕ_Z approaches ϕ .

If TFP also falls in the disaster quarter, the one-period return loss becomes $D + r^k \omega_0$ and the sign condition becomes $\gamma\lambda > 1 + r^k \omega_0/D$, a small shift of order r^k ; the annuitised effect on λ is $O((R - 1)/R)$ and negligible. The terminal two-period problem is the exception: there the principal is not exposed to TFP but labor is, so impact TFP *compresses* λ . The steepening is a property of net income flows, i.e. of the infinite horizon.

The increments themselves are first order and partial. A transitory TFP loss slows rebuilding, which makes D_t and the gap endogenous and pushes x down. Mapping consumption recoveries to TFP recoveries is an assumption.

Disciplining τ , the permanent share and ϕ_Z . Gourio (2012) cuts capital and labor-augmenting TFP equally and permanently ($b_k = b_{\text{tfp}} = 0.43$, $p = 1.7\%$ p.a.), i.e. $\tau = 1$, and notes that the split between capital and TFP is open: WWII was mostly destruction, Russia 1917 mostly TFP. Barro (2006) measures permanent output disasters with $p \approx 1.7\%$ p.a. and a risk-adjusted size of about 43%. Nakamura et al. (2013) find a peak drop of about 29% of which roughly half is reversed (long-run loss about 14–15%), a disaster-gap persistence of 0.5 per year, and a mean duration of about six years. Hsiang and Jina (2014) find no recovery within twenty years after cyclones, a level loss of the permanent type. Gilchrist and Williams (2004) document that about a quarter of the capital stock of Germany and Japan was destroyed in WWII, while Japanese output per person roughly halved, far more than $\alpha \cdot 25\% \approx 9\%$: output fell mostly through TFP and labor, a positive gap. War and depression disasters are thus TFP-heavy and partly transitory, natural disasters closer to destruction plus a permanent level loss. The steepening is governed by the

transitory share and ϕ_Z .