Can Social Security Mitigates Natural Disaster Losses? The Case of Europe, 1998-2018

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Abstract

We analyze how a sustainable social protection platform can mitigate the final damage of any natural disaster anywhere and anytime. We propose the joint use of quantitative and qualitative methods to evaluate recovery from disaster damage. In this context, we propose a new analytical tool to evaluate disaster damage, "The Natural Disaster Damage Recovery Index Model (ξ-Model)". The natural disasters damage recovery index (ξ-Model) is based on a number of elements, and it is applied to study the relationship between social protection and natural disasters recovery. These elements are (i) total natural disasters damage (α_t); (ii) economic leaking (ε); (iii) economic desgrowth (-δ); (iv) social protection platform performance (Ω_t); (v) measurement of the social protection platform performance (Ω_t) and total natural disasters damage (αt) sensitivity analysis; (vi) reconstruction time framework (+λ); (vii) disasters damage recovery index (ξ); and (viii) natural disasters impact graphical evaluator. Finally, the ξ-Index was applied on a few European countries such as France, Germany, Italy, Netherlands, and Spain from 1998 to 2018.

JEL Classification: E65

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1. Introduction

Throughout human history, natural disasters have led to widespread destruction and losses. Natural disasters are inherently unpredictable and behave chaotically across time and space. In this paper, we propose a definition of natural disaster as follows: natural disasters are any natural event that can generate a large number of human causalities and inflict significant economic damages under varying magnitudes of environmental destruction." We further classify disasters into two large groups, high impact natural disasters and low impact natural disasters.

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At the same, we note that there are differences between natural hazard - i.e. natural physical event such as the cyclonic storms, earthquake, floods, hurricane, tsunami, typhoon, volcano eruption, droughts, and epidemics - and natural disaster - i.e. total damage from the natural hazard. In addition, natural disasters are characterized by special features such as unpredictability, chaotic behavior, vulnerability, cyclicality, and high cost. We can observe that both low and high impact disasters can vary substantially in terms of the relative proportions of human causalities versus material damages.

We propose that a sustainable social protection platform can reduce the damage from natural disasters in the short and long run. To test our hypothesis, we quantify and evaluate whether countries with stronger social protection can mitigate the damage due to large disasters. More specifically, we evaluate the relationship between social protection and natural disasters in five European countries, namely France, Germany, Italy, Netherlands, and Spain, from 1998 to 2018. We chose European countries primarily because they have a long history and tradition of social protection.

In addition, we assess the relationship between a sustainable social security platform and natural disasters recovery across different levels of vulnerability, magnitude of destruction, and reconstruction time frameworks. The assessment is based on a large database of human causalities (number of death, missing, and injury people), material damages (in monetary terms), and social protection budgets (in monetary terms).

We hope that this paper will contribute significantly towards a more systematic and accurate measurement of the relationship between a sustainable social protection platform and natural disaster recovery in any country or region under a cost-benefit analysis paradigm. While most existing studies of natural disasters focus on the quantification of natural disaster damages, we also examine the significant role of strong social protection platforms in the reconstruction process (Ruiz Estrada, 2011 and 2018).

We define a sustainable social protection platform as the entire constellation of socio-economic welfare programs that benefit the society. Socio-economic welfare programs include education, healthcare, disability, low cost housing, public infrastructure, social exclusion, unemployment insurance, immigrant integration, child care, loss of spouse or parent, and retirement programs. Social protection programs are usually managed by the central government although the private sector often contributes as a partner.

In this paper, we perform case studies of social protection platforms in France, Germany, Italy, Netherlands, and Spain, from 1998 to 2018. The long history and tradition of social protection in Europe has given rise to effective socio-economic welfare programs that help all citizens. Above all, we are interested in assessing whether strong relationship exists between a sustainable social protection platform and natural disasters recovery in the short and long run. To do so, we use the Natural Disaster Damage Recovery Model, which is laid out in the next section.

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2. An Introduction to The Natural Disaster Damage Recovery Model (ξ-Model)

The natural disaster damage recovery index (ξ-Model) is based on a number of elements, and is applied to study social protection and natural disaster recovery. The elements are (i) total natural disasters damage (α_t); (ii) economic leaking (ε); (iii) economic desgrowth ($-\delta$); (iv) total social protection platform performance (Ω_t); (v) measurement of the social protection platform performance (Ω_t) and total natural disasters damage (αt) sensitivity analysis; (vi) reconstruction time framework ($+\lambda$); (viii) disaster damage recovery index (ξ); and (viii) natural disaster impact graphical evaluator.

Step-1: The Calculation of Total Natural Disasters Damage (α_t)

The initial calculation of total natural disasters damage (α_t) seeks to find two determinants i.e. total human lives causality determinant from natural disasters "ΔL_t" and total material damage cost determinant from natural disasters "ΔM_t". First, to find the result from each determinant under the construction of two three by three matrices, we use different natural hazards represented by (i = 1, 2, 3, 4, 5, 6, 7, 8, 9). These are (1) storms, (2) earthquake, (3) floods, (4) extreme temperatures, (5) forest fire, (6) avalanches and landslides, (7) volcano eruption, (8) water scarcity and droughts, and (9) epidemics. Each value of these nine natural hazards is the growth rate. Each growth rate is calculated as the changes between the present value (t_o) and the past value (t-1) respectively. Therefore, we can proceed to calculate each determinant from two matrices. More specifically, we can calculate the total human lives causality determinant from natural disasters "ΔL_t" and the total material damage cost determinant from natural disasters "ΔM_t" according to expression 1 and 2.

The total human lives causality determinant from natural disasters "ΔL_t" uses nine growth rates to icalculate the impact of each natural hazard (i) on human lives causality, represented by $(\partial L_{i(to)} / \partial L_{i(t-1)},\ _{i=1,\,2,\ldots,\,9}) \neq 0$, to evaluates the death, injury, and missing growth rate between the present year (t_o) and the last year (t_{-1}) from storms ($\partial L_{1(to)} / \partial L_{1(t-1)}$), earthquake ($\partial L_{2(to)} / \partial L_{2(t-1)}$), floods ($\partial L_{3(to)} / \partial L_{3(t-1)}$), extreme temperatures ($\partial L_{4(to)} / \partial L_{4(t-1)}$), forest fire ($\partial L_{5(to)} / \partial L_{5(t-1)}$), avalanches and landslides ($\partial L_{6(to)} / \partial L_{6(t-1)}$), volcano eruption ($\partial L_{7(to)} / \partial L_{7(t-1)}$), water scarcity and droughts ($\partial L_{8(to)} / \partial L_{8(t-1)}$), and epidemics ($\partial L_{9(to)} / \partial L_{9(t-1)}$).

The calculation of the total material damage cost determinant from natural disasters "ΔM_t" also uses nine growth rates to calculate the impact of each natural hazard (i) on the social and private infrastructure, represented by $(\partial M_{i(to)} / \partial M_{i(t-1)},\ _{i=1,\,2,\ldots,\,9}) \neq 0$, to evaluates the damage between the present year (t_o) and the last year (t_{-1}) from storms ($\partial M_{1(to)} / \partial M_{1(t-1)}$), earthquake ($\partial M_{2(to)} / \partial M_{2(t-1)}$), floods ($\partial M_{3(to)} / \partial M_{3(t-1)}$), extreme temperatures ($\partial M_{4(to)} / \partial M_{4(t-1)}$), forest fire ($\partial M_{5(to)} / \partial M_{5(t-1)}$), avalanches and landslides ($\partial M_{6(to)} / \partial M_{6(t-1)}$), volcano eruption ($\partial M_{7(to)} / \partial M_{7(t-1)}$), water scarcity and droughts ($\partial M_{8(to)} / \partial M_{8(t-1)}$), and epidemics ($\partial M_{9(to)} / \partial M_{9(t-1)}$).

After we calculated both determinants, then we can proceed to find the total natural disasters damage rate (α_t), which is equal to the sum of the total human lives causality determinant from natural disasters "ΔL_t" and the total material damage cost determinant from natural disasters "ΔM_t" (see Expression 3).

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$$\Delta L_t = \begin{pmatrix} (\partial L_{1(to)} / \partial L_{1(t-1)}) & (\partial L_{2(to)} / \partial L_{2(t-1)}) & (\partial L_{3(to)} / \partial L_{3(t-1)}) \\ (\partial L_{4(to)} / \partial L_{4(t-1)}) & (\partial L_{5(to)} / \partial L_{5(t-1)}) & (\partial L_{6(to)} / \partial L_{6(t-1)}) \\ (\partial L_{7(to)} / \partial L_{7(t-1)}) & (\partial L_{8(to)} / \partial L_{8(t-1)}) & (\partial L_{9(to)} / \partial L_{9(t-1)}) \end{pmatrix} \quad (1)$$

$$\Delta M_t = \begin{pmatrix} (\partial M_{1(to)} / \partial M_{1(t-1)}) & (\partial M_{2(to)} / \partial M_{2(t-1)}) & (\partial M_{3(to)} / \partial M_{3(t-1)}) \\ (\partial M_{4(to)} / \partial M_{4(t-1)}) & (\partial M_{5(to)} / \partial M_{5(t-1)}) & (\partial M_{6(to)} / \partial M_{6(t-1)}) \\ (\partial M_{7(to)} / \partial M_{7(t-1)}) & (\partial M_{8(to)} / \partial M_{8(t-1)}) & (\partial M_{9(to)} / \partial M_{9(t-1)}) \end{pmatrix} \quad (2)$$

Finally, the total natural disasters damage (α_t) is equal to the sum of expression 1 and 2.

$$\alpha_t = \Delta L_t + \Delta M_t \quad (3)$$

Step-2: Economic Leaking (ε)

Economic leaking (ε) is directly connected to the total natural disasters damage (α_t). Economic leaking (ε) is calculated by applying different multi-dimensional partial derivatives to evaluate a single variable to observe all its possible changes between the present (this year) and the past (last year) [see (4)].

$$\alpha_t = \sum \partial \alpha_t{}^{n}{}_{(t+1)} / \partial \alpha_t{}^{n}{}_{(t)} \geq R_+ \leq 0 \quad (4)$$

Next step is to convert from $\Delta \alpha_t{}^n$ to $\Delta \alpha_t{}^{-n}$ [see (5)].

$$[0 \leq 1/\partial \alpha_t{}^n \geq 1] = [0 \leq \partial \alpha_t{}^{-n} \geq 1] \quad (5)$$

Initial conditions ex-ante [see (6)]

$$\alpha_t \Big|_{t=0} = 0 \quad (6)$$

Final conditions ex-post [see (7)]

$$\alpha_t \Big|_{t+1=\infty} = \infty \quad (7)$$

The final step is to determine economic leaking (ε) by dividing 1 by the final result from (4) to the power of 2. [See (8)]

$$\varepsilon = \log[1-(1/\sqrt{\alpha_t})] \quad (8)$$

Step-3: Economic Desgrowth ($-\delta$)

We define economic desgrowth ($-\delta$) (Ruiz Estrada, 2010) as a macroeconomic indicator that shows the final impact of the total natural disaster damage (α_t) on the GNP. Economic desgrowth is directly connected to economic leaking (ε) (see Expression 8). At the same time,

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economic leaking (ε) is directly dependent on total natural disasters damage (α_t). Hence, the -δ always is in function of economic leaking (ε). Therefore, economic desgrowth (-δ) is equal to the product of full total potential production output (Δ) and economic leaking (ε). Subsequently, we need to subtract full total potential production output (Δ), according to expression 9. Economic desgrowth rate (-δ) should thus be a discount rate. In addition, we assume that any economy has a maximum potential output (Δ).

$$-\delta = [[(\Delta)\ (\varepsilon)] - (\Delta)] \qquad (9)$$

The behavior of economic desgrowth rate (-δ) depends directly on economic leaking (ε). Our empirical results show that if economic leaking (ε) is larger, then economic desgrowth (-δ) shows the same behavior. The finals results calculated for the economic desgrowth rates (-δ) show that a large economic leaking (ε) magnifies economic desgrowth (-δ). Hence, -δ is directly proportional to economic leaking (ε) in the long run. Finally, we assume that economic desgrowth (-δ) and the economic leaking (ε) are intimately connected (see Expression 10 and 11). -δ always starts from zero and remains negative during its entire trajectory according to our model.

$$\uparrow -\delta = (\uparrow \varepsilon\ (\uparrow \alpha t)) \qquad (10)$$
$$\downarrow -\delta = (\downarrow \varepsilon\ (\downarrow \alpha t)) \qquad (11)$$

Step-4: Total Social Protection Platform Performance (Ω_t):

A strong total social protection platform performance (Ω_t) requires a lot of resources and hence a large full total potential production output (Δ). The total social security platform performance (Ω_t) encompasses government budgets for education (Q_1), healthcare and invalidity, (Q_2), low cost housing (Q_3), public infrastructure (Q_4), social exclusion (Q_5), unemployment insurance (Q_6), immigrant integration, (Q_7), parental responsibilities and loss of spouse or parent, (Q_8), and retirement programs (Q_9). We consolidate into a single indicator the total sum of all items in monetary terms. Hence, we are going to compare different amounts of investment between the present year investment amount (t_o) and the last year investment amount (t_{-1}). The main objective of the social security platform is designed to reduce individual risk and vulnerability for large part of the population.

$$\Omega = \sum_{i=1}^{9} Q_i \qquad (12)$$

$$\Omega_t = \partial\Omega(t_o)/\partial\Omega(t_{-1}) \qquad (13)$$

Step-5: Measurement of Total Social Protection Platform Performance (Ω_t) and Total Natural Disasters Damage (αt) Sensitivity Analysis

This indicator measures the vulnerability of any natural disaster based the simultaneous analysis of total social protection platform performance (Ω_t) and behavior of total natural

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disaster damage (αt) in different time periods. The main objective is to compares the trend of both variables.

$$\alpha t/\Omega_t = \alpha t{:}\Omega_t \quad (14)$$

Results of ($\alpha t{:}\Omega_t$) Sensitivity Analysis

The ($\Omega t{:}\alpha t$) sensitivity analysis considers two possible scenarios.

(i) If $\blacktriangle\Omega_t{:}\blacktriangledown\alpha_t$ then the social protection platform can mitigate natural disaster damage

(ii)If $\blacktriangledown\Omega_t{:}\blacktriangle\alpha_t$ then the social protection platform cannot mitigate natural disaster damage

▲: increase

▼: decrease

Step-6: Reconstruction Time Framework (+λ)

The reconstruction time framework (+λ) examines how a large total sustainable social protection platform performance (Ω_t) can accelerate disaster damage recovery in short time periods.

$$+\lambda = \partial{+}\lambda t_o(\Omega_t)/\partial{+}\lambda t_{-1}(\Omega_t) \quad (15)$$

Step-7: Disaster Damage Recovery Index (ξ)

The construction and trend of disaster damage recovery index (ξ) is directly a function of the reconstruction growth rate (+λ).

$$\xi = f(+\lambda) \quad (16)$$

Step-8: Natural Disaster Impact Graphical Evaluator

The disasters impact graphical evaluator can evaluate a large number of variables in the same graphical space at the same time. This evaluator lays out an alternative multidimensional graphical approach to analyze the behavior of a large number of variables (Ruiz Estrada, 2018). We use it to evaluate the variables of five European countries, namely France, Germany, Italy, Netherlands, and Spain (See Table 1 and Figure 1).

Table 1
Natural Disaster Impact Graphical Evaluator

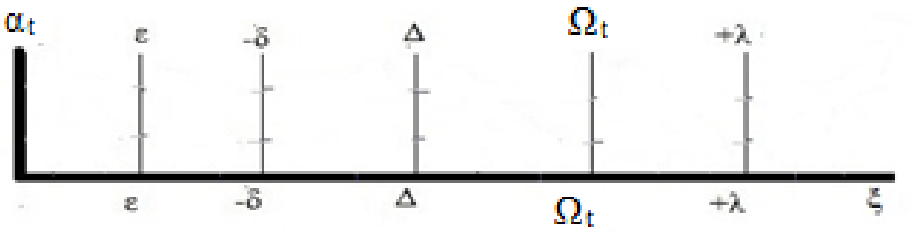
Sub-Space 1: France Windows Refraction: WR1: (ε, αt) WR2: (-δ, ε) WR3: (Δ, -δ) WR4: (Ωt, Δ) WR5: (+λ, Ωt) WR6: (ξ, +λ)	Sub-Space 2: Germany Windows Refraction: WR1: (ε, αt) WR2: (-δ, ε) WR3: (Δ, -δ) WR4: (Ωt, Δ) WR5: (+λ, Ωt) WR6: (ξ, +λ)	Sub-Space 3: Italy Windows Refraction: WR1: (ε, αt) WR2: (-δ, ε) WR3: (Δ, -δ) WR4: (Ωt, Δ) WR5: (+λ, Ωt) WR6: (ξ, +λ)

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Sub-Space 4: Netherlands Windows Refraction: WR1: (ε, αt) WR2: (-δ, ε) WR3: (Δ, -δ) WR4: (Ωt, Δ) WR5: (+λ, Ωt) WR6: (ξ, +λ)	Sub-Space 5: Spain Windows Refraction: WR1: (ε, αt) WR2: (-δ, ε) WR3: (Δ, -δ) WR4: (Ωt, Δ) WR5: (+λ, Ωt) WR6: (ξ, +λ)	

Source: (Ruiz Estrada, 2018)

Fig. 1
The Natural Disasters Impact Graphical Evaluator: Sub-Space and Windows Refraction



α_t = the total natural disasters damage
ε = the economic leaking
$-\delta$ = the economic desgrowth
Ω_t = the social protection platform performance
$+\lambda$ = the reconstruction time framework
ξ = the disasters damage recovery index

Source: (Ruiz Estrada, 2018)

3. The Application of the Natural Disaster Damage Recovery Model (ξ-Model) to France, Germany, Italy, Netherlands, and Spain, 1998-2018

The results from the natural disaster damage recovery model (ξ-Model) shows that the vulnerability of France, Germany, Italy, Netherlands, and Spain to natural disasters such as storms, floods and earthquakes was constant. Italy and Spain suffered an average total natural disaster damage (α_t) of 0.79 (1998) and 0.82 (2018). Over the last two decades, the average total natural disaster damage (α_t) in Italy and Spain considerably increased the average economic leaking (ε) of the two countries from 0.29 (1998) to 0.37(2018). The fast expansion of the economic leaking (ε) in Italy and Spain directly expanded their average economic desgrowth from -0.09 (1998) to -0.17(2018). In addition, we observe that the average full total potential output (Δ) of Spain and Italy experiences a stagnation in 2008, as a result of the global financial crisis, with a value of 0.02. The poor performance of the average full total potential output (Δ) due to the global financial crisis affects the average total social protection platform performance (Ω_t) of Italy and Spain. The fiscal consolidation after that game-changing crisis considerably reduced some social welfare programs in parts of Europe, especially Spain and Italy (See Table 2 and Figure 2).

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The average total social protection platform performance (Ω_t) and the average total natural disasters damage (αt) sensitivity analysis of Italy and Spain generates results in three different periods - 1998 (8:2), 2008 (7:3), and 2018 (5:5). This means that the average total social protection platform performance (Ω_t) of Italy and Spain were reduced substantially. At the same time, the two countries' natural disaster vulnerability increased. The results show that Ω_t of Italy and Spain fell by around 50% while the probability of damage from a natural disaster rose by 100% relative to 1998 and 2008. As a result, the average reconstruction time ($+\lambda$) of Italy and Spain increased from one year in 1998 to two years and six months in 2018. For the two countries, rebuilding infrastructure takes a longer time than before. Hence, we can observe that the disaster damage recovery index (ξ) increase from 0.07 in 1998 to 0.37 in 2018. (See Table 2 and Figure 2).

In France, Germany and Netherlands, the average total natural disaster damage (α_t) was 0.37 in 1998 and 0.40 in 2018. These results significantly affect average economic leaking (ε = 0.29, 0.18, 0.37) and average economic desgrowth ($-\delta$ = -0.09, -0.05, -0.17) in France, Germany and Netherlands. These values are lower than in Italy and Spain. The three countries have a higher average full total potential output (Δ), which directly influences the average total social protection platform performance (Ω_t). The average total social protection platform performance (Ω_t) and the average total natural disaster damage (α_t) sensitivity analysis of France, Germany, and Netherlands generates results in three different periods -1998 (9:1), 2008 (8:2), and 2018 (7:3). Those results show that France, Germany, and Netherlands have strong social protection platforms that mitigate the adverse impact of natural disasters. On the other hand, the vulnerability of the three countries to natural disasters increased considerably in recent years. According to our results, the average reconstruction time ($+\lambda$) of France, Germany, and Netherlands didn't change from one-year reconstruction (1998) to one-year reconstruction in year 2018. Finally, the disaster damage recovery index (ξ) of France, Germany, and Netherlands - ξ = 0.03 (1998), 0.07 (2008), 0.11 (2018) – outperforms that of Italy and Spain (See Table 3 and Figure 2).

Table 2
The Natural Disaster Impact Graphical Evaluator Final Results from Italy and Spain (1998-2018)

Variables	1998	2008	2018
The Total Natural Disasters Damage (α_t)	0.79	0.63	0.82
The Economic Leaking (ε)	0.29	0.18	0.37
The Economic Desgrowth ($-\delta$)	-0.09	-0.05	-0.17
The Full Total Potential Production Output (Δ)	0.07	0.03	0.08
The Total Social Protection Platform Performance (Ω_t)	0.09	0.02	0.06
Ωt and αt Sensitivity Analysis	8:2	7:3	5:5
The Reconstruction Time Framework ($+\lambda$)	1 year	2 years	2.5 years
The Disasters Damage Recovery Index (ξ)	0.07	0.19	0.37

Sources: (Centre for Research on the Epidemiology of Disasters –CRED-, 2018)
(European Environment Agency, 2018)
(Munich RE Group, 2018)

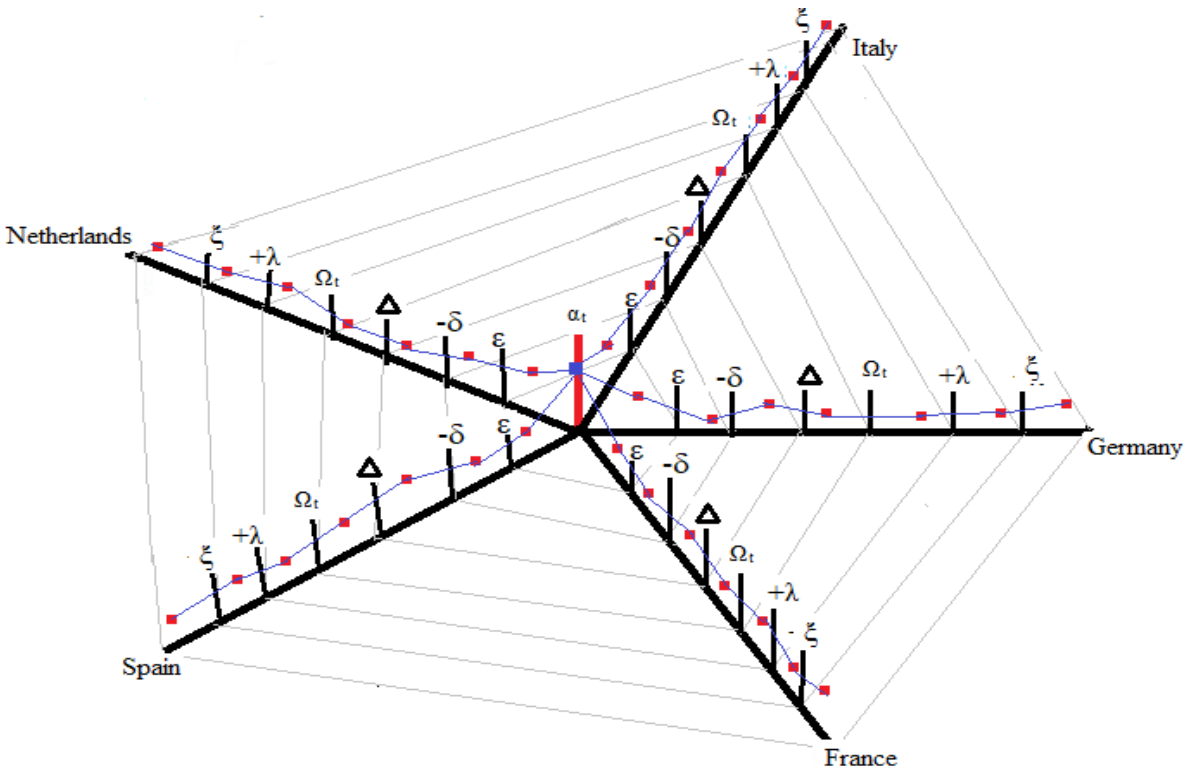
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Table 3
The Natural Disaster Impact Graphical Evaluator Final Results from France, Germany, and Netherlands (1998-2018)

Variables	1998	2008	2018
The Total Natural Disasters Damage (α_t)	0.37	0.38	0.40
The Economic Leaking (ε)	0.12	0.11	0.16
The Economic Desgrowth ($-\delta$)	-0.03	-0.09	-0.02
The Full Total Potential Production Output (Δ)	0.17	0.06	0.23
The Total Social Protection Platform Performance (Ω_t)	0.15	0.10	0.19
Ωt and αt Sensitivity Analysis	9:1	8:2	7:3
The Reconstruction Time Framework ($+\lambda$)	1 year	1 year	1 years
The Disasters Damage Recovery Index (ξ)	0.03	0.07	0.11

Sources: (Centre for Research on the Epidemiology of Disasters –CRED-, 2018)
(European Environment Agency, 2018)
(Munich RE Group, 2018)

Fig. 2
The Application of the Natural Disaster Damage Recovery Index (ξ-Index) in Europe (1998-2018): France, Germany, Italy, Netherlands, and Spain



Sources: (Centre for Research on the Epidemiology of Disasters –CRED-, 2018)
(European Environment Agency, 2018)
(Munich RE Group, 2018)

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4. Conclusion

Intuitively, stronger social protection platforms should be an important tool for mitigating the adverse effect of natural disasters. The overriding objective of social protection is to protect individuals from the various risks and vulnerabilities arising from the unexpected negative shocks that arise during a lifetime. Natural disaster is a classical example of such a shock. In this paper, we propose a new model for formally describing the relationship between natural disasters and social protection platforms, namely the Natural Disaster Damage Recovery Index Model. The model is based on the joint use of quantitative and qualitative methods to evaluate recovery from disaster damage, and rests on eight relevant structural elements.

The versatile Natural Disaster Damage Recovery Index Model can be applied flexibly to analyze the relationship between social protection and natural disasters. The model is applicable to any kind of social protection platform and any kind of natural disaster. In this paper, we apply the model to five European countries. Our results indicate that in terms of coping with natural disasters, countries with larger social protection platforms – France, Germany and Netherlands – outperform countries with smaller social protection platforms – Italy and Spain. Our evidence thus provides some support for the notion that social protection mitigates the human and material damage of natural disasters.

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