Regional economic impacts of the 2013 heavy flooding events in Germany

Abstract

During May and June 2013 heavy rains caused disastrous flooding events in severeal countries in Europe. For Germany's eastern and southern federal states it has been the third flooding event since 1997. Due to the heavy reliance of modern economies on interregional supply chains, substantial impacts on economies in regions not directly affected by the flooding are felt.

In this study we are using a new high-resolution model of the german econnomy (GerMRIO) to simulate the post-disaster economic shock. Industries linked by interregional trade would almost fell 50% of the economic impact in terms of reduced production possiblities. The impact on german wide production possibilities would a reduction of 0.7% or 23 billion USD.

Introduction:

The south and the south-east of Germany has been frequently hit by catastrophic flooding events in the last 20 years, especially the regions along the Elbe, Oder and Danube rivers. The flooding of Elbe, Danube and their tributaries in May and June 2013 is concidered as the third “flooding of the century” since 1997. The economic costs of natural disasters in Germany have risen in the last decades and are expected to increase due to climate-change in the next decades (0). According to a provisional report from September 2013 elaborated by the Federal Ministry of the Interior[1] damages to public infrastructure, equipment, residential and commercial builings is estimated at 6.4 billion Euros in the particularly affected states of Bavaria, Saxony, Saxony-Anhalt and Thuringia, which is approximatly 1% of their gross regional product. More recent estimates published by the reinsurance company Munich RE (2) suggest that the flooding was the worldwide most severe catastrophe in terms of economic damage. Economic damages in Germany alone are estimated at about 10 billion Euros. These, however, are only estimates of the direct costs of a natural disaster for the repairing or replacement of buildings and infrastrucutre.

Figure: From the 2013 flooding endangered areas in South and East Germany

In addition the direct damages to an economy hit by a natural disaster are followed by indirect costs such as business interruptions or losses in production capacities. Due to the heavy dependence on inter-regional and international trade of modern eonomies, the 2013 flooding

[1] https://www.bmi.bund.de/SharedDocs/Downloads/DE/Broschueren/2013/kabinettbericht-fluthilfe.pdf?__blob=publicationFile

disaster can be expected to induce a cascade of flow-on effects on other regional economies in Germany. For the quantification of indirect economic consequences Input-Output models are a widely used tool to analyse how shocks are propagated through complex supply-chains of an economy (3,4,5,6).

Due to the absense of multiregional Input-Output (MRIO) data, the majority of studies focus on a single region or country, omitting regional spillover and feedback effects through interregional and international trade. The development of global MRIO databases such as EORA or WIOD (7,8) allow for the analysis of global impacts of catastrophies such as severe space weather events (9) or the 2011 Japanese desaster (10). On the subnational level Richardson et al. (11) analyse the impacts of terrorist attacks with a MRIO for the metropolitan area of Los Angeles.

The quantification of the indirect impacts of the 2013 flooding disaster on the economies of Germany's federal states is the aim of this paper. For this purpose we make use of German MRIO data for the 16 federal states. In order to account for the effects on other countries additionally, global MRIO data from EORA is utilized.

Methodic and results sections for German flood paper:

In order to quantify the economic impacts of the 2013 flooding in Germany we simulate the consequences of major disasters (5) by utilizing Leontief's input-output (IO) theory (12). IO analysis has been used extensively for investigating the repercussions of changes in one part of an economy on other parts of the same economy (see recent articles in *Nature* [13] and *PNAS* [14]). Most often, productive activity in modern economies is assumed to be demand-driven, and the so-called demand-pull model is evoked, where an initial change vector $\Delta\mathbf{y}$ in final demand $\mathbf{y}$ (N×1, for example decreased household consumption caused by reduced supply) causes flow-on effects that ripple through a complex supply-chain network, and ultimately leads to a change $\Delta\mathbf{x}$ in total output $\mathbf{x}$ (N×1) of an economy. The scalar N holds the number of sectors (industries and/or products) that are distinguished in the IO matrices. The flow-on effects can be enumerated using an N×N input-output transactions matrix $\mathbf{T}$, according to $\Delta\mathbf{x} = (\mathbf{I} - \mathbf{T}\hat{\mathbf{x}}^{-1})^{-1}\Delta\mathbf{y} = (\mathbf{I} - \mathbf{A})^{-1}\Delta\mathbf{y}$, where $\mathbf{I}$ denotes an N×N identity matrix, the hat symbol '^' denotes matrix diagonalisation, and $\mathbf{A} = \mathbf{T}\hat{\mathbf{x}}^{-1}$ is the matrix of input coefficients. This relationship follows from the National Accounting Identity, which states that $\mathbf{x} = \mathbf{T1} + \mathbf{y} = \mathbf{Ax} + \mathbf{y}$, where $\mathbf{1} = \{1,1,\ldots,1\}'$ is an N×1 summation operator. A transaction matrix $\mathbf{T}$ is essentially a square matrix with elements T_{uv} that represent the supply of products u for use in industry v. Matrices $\mathbf{T}$ and $\mathbf{A}$ thus include information on industrial interdependence and production structures in an economy, which can ultimately be used to trace flow-on effects of initial changes along supply chains that link all sectors in an economy. Input-output databases including data on $\mathbf{T}$, $\mathbf{y}$ and $\mathbf{x}$ are routinely published by more than 100 national statistical bureaus in the world. More recently, a number of teams have assembled large-scale, detailed global and interregional Multi-Regional Input-Output (MRIO) databases, which contain the same set of data ($\mathbf{T}$, $\mathbf{y}$ and $\mathbf{x}$) but integrated for all countries or regions (8). MRIO tables can be used in the same analytical manner as national input-output tables, for investigating effects that ripple along interregional or global supply-chain networks (15). In this study we use a MRIO table for Germany (GerMRIO) with N = 1727 region-sectors pairs using data from 2007 (**Error! Reference source not found.**). Final demand is for M = 16 federal states with 10 final demand sectors each. In addition, we utilize the most detailed of the global MRIO database, distinguishing 15,909 country-sector pairs (7,17) using data from 2010. Here, final demand is for 14,761 sectors in 187 countries with 6 final demand sectors each.

Rather than following the effects of changes in final demand on levels of total output, we analyze a situation where the output of some economic sectors undergo forced changes, and study the effects that these changes have on final demand or production possibilities in other sectors. Such studies are generally known as disaster impact analysis (4). Our approach to estimating the direct and indirect consequences of a flooding event affecting a specific set of regions $R = 1,\ldots,M$ and industries $u,v = 1,\ldots,N$, leads to an $N\times N$ diagonal matrix of fractions γ of production capacity lost due to the event:

$$\boldsymbol{\Gamma}(R,P) = \begin{bmatrix} \gamma_{R=1,P=1} & & \\ & \ddots & \\ & & \gamma_{R=M,P=N} \end{bmatrix}‘$$

with $0 \le \gamma \le 1$.

$\boldsymbol{\Gamma}$ has entries in industrial sectors directly and indirectly affected by the flooding. Direct damages to regional output capacities are then used to account for indirect economic impacts in other federal states or other industrial sectors within that region. Assume pre-disaster production is represented by total output $\mathbf{x}$. The post-disaster production possibilities are then

$$\tilde{\mathbf{x}} = (\mathbf{I} - \boldsymbol{\Gamma})\,\mathbf{x}.$$

This formulation is equivalent to the model in Eqs. 17 and 21-23 in (5). The result of a reduced industrial production $\tilde{\mathbf{x}}$ is a state of reduced post-disaster consumption possibilities, i.e. final demand $\tilde{\mathbf{y}}$. Since $\mathbf{A}\tilde{\mathbf{x}} + \mathbf{y} \neq \tilde{\mathbf{x}}$, the National Accounting Identity does not hold after the disaster, and the national economy is in imbalance. In particular, the reduced output is insufficient for satisfying final demand $\mathbf{y}$. Reduced post-disaster consumption possibilities are

$$\tilde{\mathbf{y}} = \tilde{\mathbf{x}} - \mathbf{A}\tilde{\mathbf{x}}\ .$$

Note that this formulation assumes that the post-disaster input coefficients **A,** the production recipe, is the same as pre-disaster, meaning that at least in the short term (within a year), production processes in the affected industries cannot be altered in order to make up for lost production capacities.

Assume that the loss of production in sector d directly affected by the flood is represented by $\Delta x_d = \gamma_{d*}\, x_d$. This loss affects supply to households (Δy_d) and to other industrial sectors (ΔT_d) and is distributed according to $y_d/x_d = \Delta y_d/\Delta x_d$. We assume the fraction of production capacity lost in an indirect affected sector i is $\gamma_{i\neq d} = \Delta y_d/y_d = \Delta T_d/T_d$. We generally find

$$\frac{\Delta T}{\mathrm{T}} = \frac{\Delta x - \Delta y}{x - y} = \frac{\frac{\Delta y}{D} - \Delta y}{\frac{y}{D} - y} = \frac{\Delta y(\frac{1}{D} - 1)}{y(\frac{1}{D} - 1)} = \frac{\Delta y}{y}.$$

Thereafter final and intermediate demand is relatively (not absolute) curtailed equally. If $\Delta x = \Delta y$, i.e. $\Delta T = 0$, one would take a conservative approach and actually minimize total economic damage. This is because the impact on supply chains and interregional trade is missing from the assessment of the damage caused by the flooding. Only final demand would be affected and only in those regions directly affected by the flood (Figure 1).

Figure 1: Post-disaster consumption possibilities in Germany are reduced due to the flood in Saxony-Anhalt by 0.8%, Saxony (0.5%), Thuringia (0.4%), and Bavaria (0.1%) in a conservative impact scenario.

For a more realistic scenario we examine the Leontief inverse or total requirement matrix $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$ (Figure 2). We then see that the lost supply from directly damaged sectors is quite an important production input for some sectors, but a very small input for others. If it is a very small input (we define a threshold for small) we decide that this sector is not hit by the interregional cascade, e.g. because this sector can substitute the small input with some other good. For a sector where the input from directly damaged sectors is a significant input ($L_{R,u}$ > threshold) we reduce the output of that sector as described above. The threshold is determined according to the total national requirement from supply of sectors directly damaged due to the flooding (Figure 2). The addition of all rows values in L corresponding to directly affected sectors in Table 1 shows that most of their supply is purchaised to 4 sectors only: Manufacturing and recycling, agriculture, and water transport, and Fish and other product and fishing services incidental of fishing. The supply to 1721 other sectors is less than 10% of the total production requirement of directly affected sectors. From Figure 2 we set the threshold to 0.2.

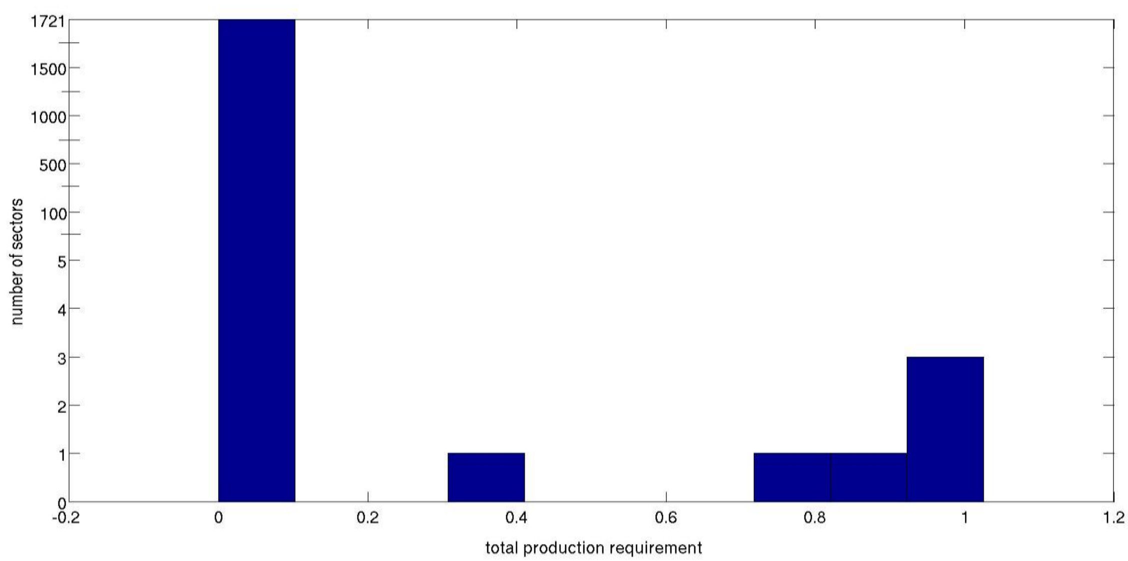

Figure 2: Total production requirement of supply from directly affected sectors.

Data:

Input-Output analysis of natural disasters is generally hampered by the scarcity of information about direct damages to sectoral production capacities, in particular on the regional level. For this reason proxy information from national or regional accounts is often used instead, e.g. monthly industrial production indices (18). The sectoral levels of production, however, are influenced by many other variables, such as business cycles or excess capacity (19), which can distort estimates of production capacity loss rates.

For this analysis we make use of statistics about the so-called short-time allowances (Kurzarbeitergeld), which is part of the public unemployment insurance. If a company is faced with an unexpected decrease in production due to an external event, such as natural disasters or economic crises, the unemployment insurance compensates 60% of lost working hours. The Federal Employment Agency provided us with monthly time series data about the number of workers receiving payment from the short-time allowances for 41 industries per region. The rates of lost capacity $\boldsymbol{\Gamma}$ are estimated as the sectoral shares workers receiving payment from the short-time allowances in total sectoral employment in the month of May to June (Table 1).

	BY	S	SA	T
Agriculture, Hunting, Forestry and Fishing	0.00%	0.08%	0.12%	0.02%
Mining and Quarrying	0.00%	0.08%	0.01%	0.00%
Food, Beverages and Tobacco	0.02%	0.18%	0.03%	0.06%
Textiles and Textile Products	0.30%	0.85%	0.16%	0.95%
Leather, Leather and Footwear	0.15%	0.32%	1.21%	0.50%
Wood and Products of Wood and Cork	0.09%	0.18%	0.16%	0.34%
Pulp, Paper	0.16%	0.71%	0.00%	0.27%
Printing and Publishing	0.06%	0.48%	0.08%	0.26%
Coke, Refined Petroleum and Nuclear Fuel	0.03%	0.00%	0.00%	0.00%
Pharmaceuticals	0.13%	0.00%	0.00%	0.00%
Chemicals and Chemical Products	0.05%	0.22%	0.07%	0.36%
Rubber and Plastics	0.33%	0.35%	0.05%	0.34%
Glass and Glass products	0.21%	0.36%	0.18%	0.42%
Other Non-Metallic Mineral	0.00%	0.00%	0.00%	0.00%
basic ferrous metals	0.21%	0.36%	0.18%	0.42%
basic precious metals and other non-ferrous metals	0.00%	0.00%	0.00%	0.00%
foundry work services	0.00%	0.00%	0.00%	0.00%
Fabricated Metal	0.17%	0.34%	0.28%	0.27%
Machinery, Nec	0.27%	0.47%	0.62%	0.30%
Electrical and Optical Equipment	0.25%	0.62%	0.48%	0.55%
Transport Equipment	0.07%	0.30%	0.52%	0.50%
Manufacturing, Nec; Recycling	0.16%	0.21%	0.20%	0.29%
Electricity, Gas and Water Supply	0.01%	0.01%	0.00%	0.06%
Construction	0.05%	0.15%	0.13%	0.13%
Sale, Maintenance and Repair of Motor Vehicles and Motorcycle	0.04%	0.10%	0.17%	0.08%
Wholesale Trade and Commission Trade, Except of Motor Vehic	0.03%	0.04%	0.07%	0.07%
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair	0.00%	0.09%	0.03%	0.02%
Hotels and Restaurants	0.02%	0.32%	0.21%	0.08%
Inland Transport	0.00%	0.02%	0.02%	0.01%
Water Transport	0.16%	3.19%	1.36%	0.00%
Air Transport	0.00%	0.00%	0.00%	0.00%
Other Supporting and Auxiliary Transport Activities; Activities o	0.03%	0.04%	0.03%	0.01%
Post and Telecommunications	0.06%	0.04%	0.07%	0.05%
Financial Intermediation	0.00%	0.01%	0.03%	0.00%
Real Estate Activities	0.00%	0.07%	0.07%	0.06%
Renting of M&Eq and Other Business Activities	0.02%	0.05%	0.09%	0.04%
Public Admin and Defence; Compulsory Social Security	0.00%	0.00%	0.00%	0.00%
Education	0.00%	0.00%	0.01%	0.00%
Health and Social Work	0.00%	0.02%	0.01%	0.01%
Other Community, Social and Personal Services	0.05%	0.07%	0.05%	0.01%
Private Households with Employed Persons	0.00%	0.00%	0.00%	0.00%

Table 1: Compensations of lost working hours from social insurance schemes for the 2013

flooding in Germany (Source: BA/own calculations)

Results:

In all scenarios we see economic damage not only in those regions directly affected by the flood, but also in partner regions affected due to disruptions in interregional trade and supply chains. This is because industries that rely directly or indirectly on supplies from the directly damaged sector(s), face input shortages, and hence have to scale back their production. However, we also find that some regions are faced with increases in consumption possibilities. This is because industries producing inputs that are directly or indirectly required by the damaged sector(s). After the flooding part of these inputs are not needed anymore since the damaged sector(s) operates at reduced capacity, and hence the output of the industries producing these inputs is available for additional domestic and regional consumption. Whilst the latter situation provides in principle increased consumption possibilities, our model does not reveal whether adequate final demand will in fact be forthcoming to absorb the surplus production capacity. For the purpose of this study, we simply report on two types of economic imbalances, where a) shortages of inputs lead to production deficits and curtailed demand, and where b) reduced demand for inputs by directly damaged sector(s) leads to surplus production that may remain unused.

We show results for a scenario where final and intermediate demand is curtailed equally by reduced supply from directly damaged sectors by the flooding (Figure 3). The heaviest relative reduction in production possibilities would be in Thuringia (-1.6%), Saxony-Anhalt (-1.4%), Bavaria (-1.3%), and Saxony (-1.0%). That is in those regions where the flooding occurred. The heaviest indirect affected regions are Mecklenburg-Vorpommern (-0.8% production possibilities), Hamburg (-0.7%), and Bremen (-0.4%). This is because the manufacturing industry of Mecklenburg-Vorpommern, e.g. office machinery and computers, is dependent on supply from Bavaria and Saxony. In Hamburg the aviation industry suffers from reduced supply in particular from Saxony and Bavaria. In Bremen the manufacturing industry is strongly dependent from supply of the industry in directly affected regions.

The heaviest absolute affected sectors in this scenario are the production of secondary raw materials (-1.7 billion €), Post- and Telecommunication (-1.6 billion €) and Inland Transport (-1.2 billion €) in Bavaria. They are followed by the rubber and plastic sector in Baden-Wuerttemberg (-0.9 billion €), and Fish and other fishing products and services incidental of fishing in Northrhine-Westfalia (-0.9 billion €) and Pharmaceuticals in Bavaria (-0.8 billion €). Region wide Bavaria would face an absolute loss in production possibilities of almost 16 billion €, followed by Northrhine-Westfalia with 5 billion € and Saxony with 1.3 billion € (Figure 4).

Post-disaster consumption possibilities are higher in all regions due to the flooding because final demand is able to shoulder the entire loss.

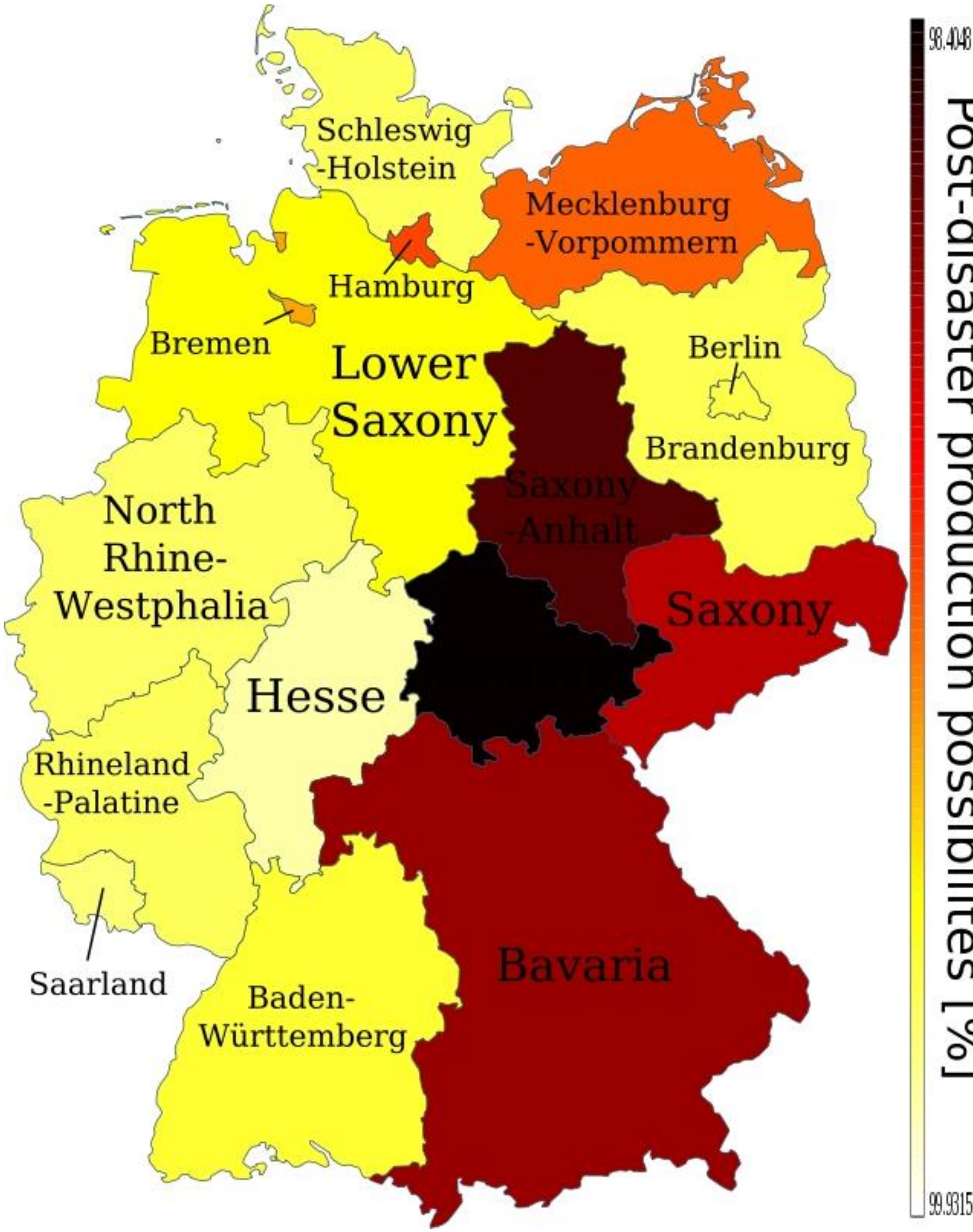

Figure 3: In a more realistic impact scenario all regions are affected by the flood, either direct or indirect. Thuringia lost 1.6% of its production possibilities, Saxony-Anhalt 1.4 %, Bavaria 1.3%, and Saxony 1.1%. Overall Germany lost 0.7 % of its production possibilities.

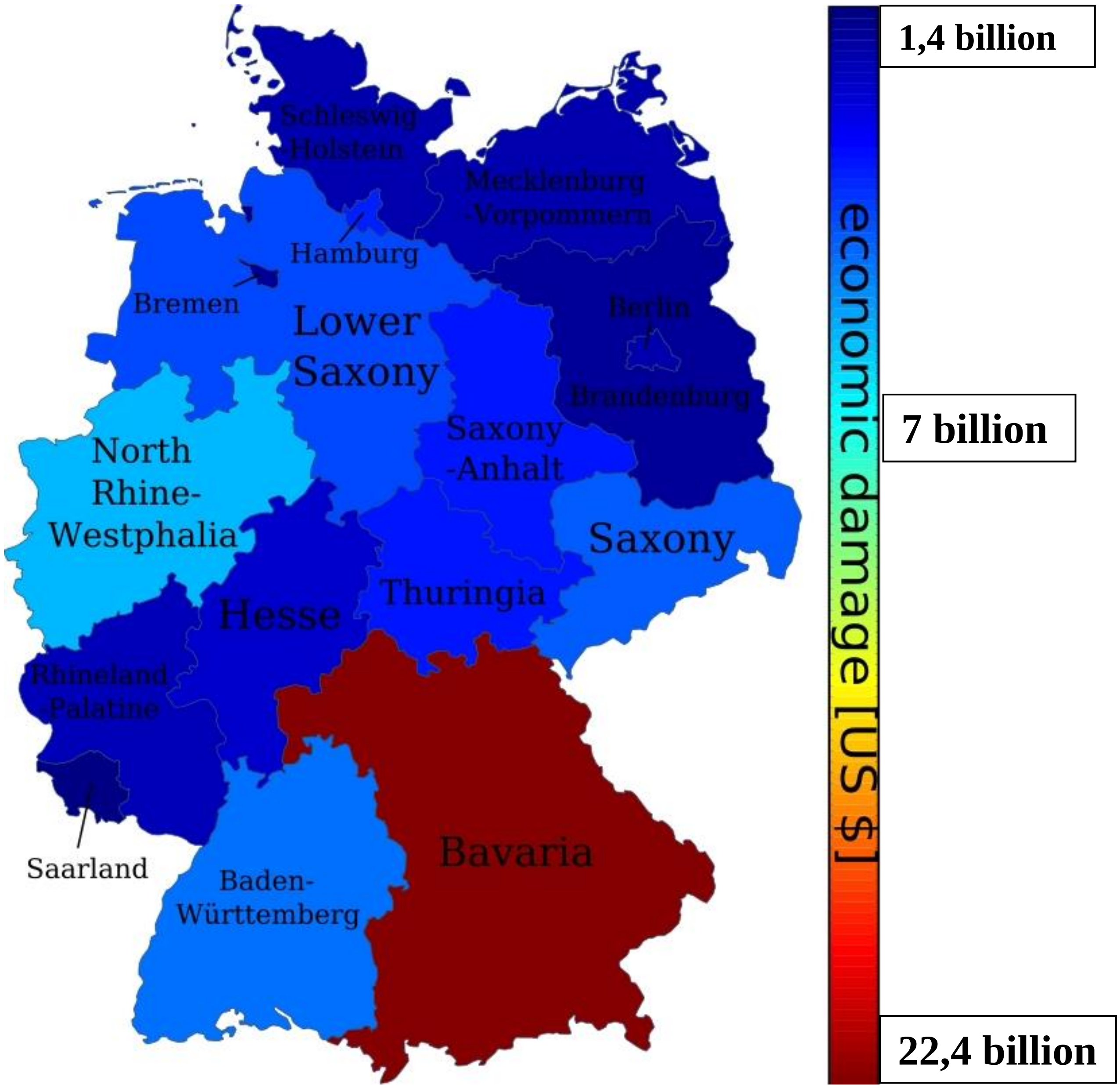

Figure 4: Absolute loss in production possibilities per federal state.

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