The Geneva Papers on Risk and Insurance - Issues and Practice (2021) 46:224–235
https://doi.org/10.1057/s41288-021-00217-7

Vulnerability and mutual insurance

Roland Eisen[1]

Accepted: 24 February 2021 / Published online: 22 April 2021

Abstract
Vulnerability comes, according to Orio Giarini, with two risks: human-made risks, also called entrepreneurial risks, and natural or pure risks such as accidents and earthquakes. Both types of risk are growing in dimension and are increasingly interrelated. To control the vulnerability, sophisticated insurance products are called for. Here, mutual insurance is relevant, in particular when risks are large, probabilities uncertain or unknown, and events interrelated or correlated. In this paper the following three examples are discussed and the advantages of mutual insurance are shown: unknown probabilities connected with unforeseeable events, correlated risks and macroeconomic or demographic risks.

Keywords Mutuality principle · Unknown probabilities · Correlated risks · Macroeconomic risks

Setting the stage and definitions

Vulnerability, or even increasing vulnerability, is not only a phenomenon of the First (and subsequent two) Industrial Revolutions, but also of the post-industrial economy, and the new Industrial Revolution 4.0.

Almost half a century has passed since Orio Giarini wrote about economics and vulnerability and the consequences for risk management and insurance (Giarini 1977, 1984; Giarini and Loubergé 1976, 1978).[1] By vulnerability Orio Giarini means "the situation of a system (be it an industry, a group or a national economy) in which survival is imperilled by some specific events, acts or failures to act …(so that, RE) … the system is destroyed or at least fundamentally modified" (Giarini 1977, p. 47). According to him, vulnerability comes with two types of risks, which are interlinked in most cases: human-made, also called 'entrepreneurial risk implicit in a voluntary action', and natural or pure risks, which depend 'on unforeseeable

[1] See Giarini (1977, 1982) and Giarini and Loubergé (1976, 1978).

✉ Roland Eisen
eisen@wiwi.uni-frankfurt.de

[1] Goethe University Frankfurt, Frankfurt, Germany

events', such as earthquakes and accidents (Giarini 1977, p. 47). Furthermore, the increasing vulnerability of the economic system, can be expressed by two phenomena: a) both types of risks are of growing dimensions due on the one hand to direct technological effects (concentration of production, dependency of scientific technology) and on the other hand to the growth of interdependence, which increases the number of factors involved in the functioning of the system and which can be exposed to a break down; and b) both types of risks are increasingly interrelated, the higher the vulnerability levels the greater the need for coordinated management of the two aspects of risk (Giarini 1977, p. 47).

Taken together, "vulnerability is the result of a paradoxical evolution. The more sophisticated a technology, the narrower the range of tolerable error because accidents and managerial failures have more severe consequences" (Zweifel et al. 2021, p. 6). Risk management and insurance must adapt their approach to "be able to cover the really large and really difficult risk which advancing technology is making more and more common" (Crockford 1976, p. 15). To control the vulnerability, sophisticated insurance products are called for! Here enters the mechanism of mutual insurance, which is especially relevant when risks are large, probabilities are uncertain or unknown and events interconnected or correlated.

In the following, I will show how Orio Giarini's two trends and their consequences for vulnerability can be used in the theory of mutual insurance. This is the heart of the third section, Practical use of mutual insurance. Beforehand, the theoretical background of different insurance mechanisms or 'theories' will be elucidated in short. A summary will conclude the arguments.

Theoretical background

In principle, there are today three different 'theories of insurance' in the economic literature. The theory accepted almost everywhere was formulated by Allan Willett, who defined insurance as "the fund accumulated to meet uncertain losses" (Willett 1901, p. 71). The insurance company exists, therefore, because of the increasing returns inherent to the accumulation of reserves. This *reserve theory of insurance* is based upon the application (and applicability) of the law of large numbers and the central limit theorem. This means an increase in the number of insureds in a portfolio tends to lead to a concentration of the probability density of the average loss around the mean value.

This *reserve theory* stands in stark contrast to a concept developed in modern economic theory, which looks at insurance as a trade in 'contingent claims': insurance is the exchange of money now for money payable tomorrow, contingent on the occurrence of certain events. This theory, which goes back to Arrow (1970), will be called, therefore, *mutuality theory of insurance*. Insurance companies are intermediaries which sell their preferred bundle of contingent claims (or 'ideal insurance policies') to economic agents.

This second theory has close relations with a third concept, which looks at insurers as financial intermediaries on the capital market, here called *capital market* *theory*. On the one hand, the selling of insurance contracts is seen as the selling of contingent assets; on the other hand, the proceeds are invested on the capital market. Hence, insurance companies are sellers and buyers of assets. Insurance contracts are, therefore, a subset of all financial assets of an individual portfolio.

Qualitatively, *mutuality theory* and *capital market theory* are almost identical. However, the differentiation is interesting because the *mutuality theory of insurance* allows a higher degree of diversification and specification of insurance contracts.[2]

Assuming equivalence between Arrow's *ideal insurance model* and *mutuality theory*, some theoretical arguments with respect to the traditional *reserve theory* can be given.[3]

The classical *reserve theory* starts with an additive principle of premium calculation (see Borch 1974, p. 128), where the most general form is given by

$$p(F(X)) = \Sigma_m p_m k_m$$

for $m = 1,\ldots,\infty$. This can be written[4] for a normal distribution

$$p(f(x)) = p_1 k_1 + k_2 p_2 = E(x) + p_2 \sigma^2$$

for $p_1 = 1$, and for a Poisson distribution

$$F(X = b) = \left(\lambda^b / b!\right) e^{-\lambda}$$

we arrive at

$$p(F(x = b) = \lambda \Sigma p_m = A.E(x),$$

because all cumulants are equal to λ and A is a constant.

If the price (or the premium) is given by

$$p(F(x)) = E(x) + p\sigma^2$$

then, at the beginning, the total value of all loss distributions is given by ($i = 1, \ldots, n$ as individuals)

$$\Sigma_i (E^i\left(x_i\right) + p\sigma_i^2) = E(x) + p\sigma^2,$$

where $x = \Sigma_i x_i$ and $\sigma^2 = \Sigma_i \sigma_i^{\,2}$, if x_i is stochastically independent.

For a Pareto optimal loss arrangement, where every insurer pays a fixed quota z_i of the amount of claims against the 'pool' ($x = \Sigma_i x_i$), the total value is given by

[2] For a critical evaluation of 'mutuality theory' and 'capital market theory', see Doherty (1984), Marshall (1974), Mayers (1976) and Venezian (1983).

[3] The following section is based on Eisen (1979). For a more recent approach, see Gatzert and Schmeiser (2012).

[4] Here, p(F(X)) represents the price of the loss distribution F(X), f(x) for the marginal distribution; k_m is the mth cumulant of the distribution; k_1 is the mean (or expected value); and k_2 is the variance.

$$\Sigma_i\left(z_i E^i\left(x_i\right) + p z_i^2 \sigma_i^2\right) = E(x) + p\Sigma_i z_i^2 \sigma_i^2.$$

However, in general, the last term of this equation will be different from $\sigma^2 = \Sigma_i \sigma_i^2$. This difference reflects the fact that insurance is a ‘mechanism’ that changes the total risk, i.e. the aggregate risk is not equal to the sum of the individual risks (measured by the variance of the probability distribution). This is behind the law of large numbers: it is ‘cheaper’—under certain restrictions—to pool the reserves and to apply the law of large numbers.

In contrast, in the *ideal or mutuality theory* there exists a price for every state of nature which is the same for every state only if the total losses are the same. Then, this equilibrium price set supports a consumption and income distribution over all members, which is—given the expected utility—Pareto optimal.

However, given certain assumptions, the two concepts are identical; first, if the total income in all states is the same. Here, the prices of the Arrow certificates are proportional to the probabilities. Also, the total loss is given; therefore, it is no problem to determine the adequate reserves (and the risk loading). The actuarial prices of both concepts are the same. Second, for large sets of independent (individual) risks, the difference between the two concepts disappears. This result is also based on the law of large numbers. Supposing there are n consumer-agents with identical preferences, incomes and expected losses, then every individual has utility U(.), the income $y_i(s) = y$ (with $s = 1, \ldots, m$ representing the states of nature) in the no-loss state and income $y_i(s) = y - x$ in the loss state, and the probability of loss is $\pi_i = \pi$. If the losses are independent then there are 2^m ‘natural states’, but only $m + 1$ states with different incomes, and the probabilities of these states are

$$\pi(m)_b = \binom{m}{b}\pi^b(1-\pi)^{m-b}$$

where b is the number of losses. Free trade with contingent claims results in

$$y_i(s) = y - b(s)x/n,$$

where b(s) is the number of losses with size x in state s divided by the number of individuals. This equation shows that the individual income depends on the total income and the total loss divided by the number of individuals in the group.

If there is a system of normal risk-transfer contracts, then every insured pays a premium equal to the expected loss, πx, and a loading, λ_n. There may now exist a part of society, r, which insures the rest of society, $(1 - r)$; the consumption of this group is $y_i(s) = y - \pi x - \lambda_n$ with certainty. The ‘insurers’ then allocate the risk equally between them, then, they have a contingent consumption or income of

$$y_i(s) = y - (b/rn)x + (1 - r/r)\pi x + (1 - r/r)\lambda_n.$$

This equation shows that the random income of the ‘insurers’ is equal to the total income minus the sum of the losses plus the premium income they get from the ‘insured’.

The ‘cost of inefficiency’ per insured individual is then simply the difference between the utility in case the contingent claims mechanism is used multiplied by the number of agents (i.e. the probability of this event) and the utility with the risk-transfer contract:

$$L_n = \Sigma_b \pi(n)_b U(y - b(s)x/n) - U\left(y - \pi x - \lambda_n\right).$$

As Arrow and Lind (1970) have shown, λ_n and hence L_n go to zero if n increases without limit.[5]

These two arguments are, however, connected. In the second case, the total loss per head is sure, in the first case it is the certainty of the total loss which guarantees that the *reserve theory* is efficient.[6]

Given the law of large numbers, then actuarially-calculated prices for insurance contracts do not hinder the efficiency. However, if the risks are dependent or correlated, then the law of large numbers does not apply, and hence there is no insurance in the form of risk-transfer contracts. Many risks show dependencies, as discussed by Giarini (1977), and must be insured via alternative institutions. Or, in other words, vulnerability calls for sophisticated insurance products! And—as mentioned above—here, *mutual insurance theory* steps in.

Practical use of mutual insurance: three examples[7]

Second-degree uncertainty or unpredictable risks

In the simple model with contingent claims, insurers play only the role of brokers. Only when transactions costs are taken into account, and hence brokering is a productive activity connected with costs, can insurers exist as such. Furthermore, practical insurance contracts are not 'contingent claims' but complicated bundles of such claims, and the indemnity is described mostly only by the value of loss. Therefore, moral hazard comes in (see e.g. Marshall 1976), and contracts will not always be completely fulfilled. This, however, implies that insurers must hold reserves—or find other ways to secure this risk.

Besides this role, reserves are held also to level lifecycle income, insofar as reserves are savings.

However, the results of the one-period model above must hold good in every period (see e.g. Radner 1968): as far as reserves are larger than necessary for the levelling function, they are costs for society! This implies that insurers should use the advantages of reinsurance and risk pooling, à la Karl Borch, to reduce their reserves

[5] Malinvaud (1972) has shown that 'risk-neutral insurance transfers' (this means insurance contracts which are traded with actuarially fair premia) are optimal if there are only 'individual risks' and the number of agents is sufficiently large.

[6] The two concepts are also equivalent if there are quadratic utility functions, because then the market price of risk is the same for all individuals (a point which was made to me by J.-M. Graf von der Schulenburg).

[7] This part follows my paper, Eisen (2006), written in German.

considerably—and in this way the existing insurance system greatly approximates the *ideal system* of Arrow or *mutuality theory*!

Skogh (1998) has made the point that *mutuality theory* is particularly useful if the assignment of probabilities is impossible in special loss situations. It may be possible that individuals, when forced to choose between uncertain results, base their decisions on subjective estimates. However, such decisions under uncertainty are expensive—individuals are afraid of uncertainty; it is not only the assignment of subjective probabilities but also the confidence in one's beliefs (Skogh 1999, p. 508), so-called second-degree uncertainty. Here, an example given by Borch (1990, chapter 7) is cited, where he discusses the insurance of great jet propulsion airplanes. It is not the uncertainty which made the first contract so expensive—there was enough experience with normal propeller-driven airplanes and military jet-fighters—it was the low statistical information (because of the very high loading involved)!

It goes without saying that mutual insurance contracts are based on confidence and on the assumption that the individuals in the pool have similar risks and—in some sense—the same information, however hazy.[8]

Correlated risks

The aforementioned trends towards increasing vulnerability and the changing environmental and risk situations are big challenges for insurance companies. Both parts, the changing individual risk as well as the changing environment (the degree of urban concentration, the concentration of production, the interdependence of the economic system), pointed out by Giarini and Loubergé (1976, p. 48), are parts of the risk-theoretical model (see e.g. Beard et al. 1984). These transformations are part of the model risk (or risk of changing specific components), which is itself a part of the underwriting risk. On the one hand, one has to answer the question: which of these transformations are insured and which parts are not? On the other hand, one has to take into account that certain changes in the model risk, e.g. inflation (see Giarini 1977, 49 sqq.), the trade cycle, liability and indemnity rules,[9] are difficult to insure or are not insured/insurable.

Changes in law or judicial enlargements of liability rules mean instabilities, which are often causes for periodically appearing 'insurance crises' in liability and other non-life insurance markets. In connection with these factors—which appear jointly for different groups of insurance contracts—one must also take into account new industrial risks, like development risks, which are connected with new industrial processes, chemicals, nuclear power, asbestos, nanotechnologies, new drugs or vaccines etc.! They are insured only to a small degree by insurance companies (see Skogh 1998 and Giarini and Loubergé 1976).

Changes in prices and costs also have joint effects on large groups of insurance buyers, in particular in non-life insurance. But, even when correlation for certain risk types (damage types) is relatively small, the inflationary effects are highly correlated. However, these highly correlated components can be easily calculated; hence,

[8] However, see the analysis by Bourlés (2008), in particular the second chapter.

[9] Changes in law or jurisdiction as part of the 'blame game' are accelerating and 'blame and liability tend to convert in the deepest asset pools', as remarked by Murray (2012, p. 8).

new products can be developed which increase the efficiency of the risk transfer (see Doherty and Schlesinger 2002, p. 46)!

Macroeconomic risks and the consequences of catastrophes or terrorism throw up the same problems. The estimated insured highest value of losses of one single catastrophe is about USD 50 to 100 billion, with a high plausibility. This can be contrasted with the estimated total value of the insurance capacity of the non-life insurance industry of about USD 200 to 300 billion. Because these damages can be high enough to inundate or wipe out the whole insurance industry, one has to think about new risk policy or risk management alternatives. One alternative is 'securitisation' and so-called alternative risk transfer (ART) through capital markets.[10]

These examples also show a high correlation between the losses, and the optimal risk allocation contract is one in which the risk is separated into diversifiable and non-diversifiable parts. Here, the diversifiable part can be fully insured, while the non-diversifiable part cannot be insured, or only partially. "This is the essence of mutual insurance", as summed up by Doherty and Schlesinger (2002, p. 46).

Just as with the mutuality principle discussed above, the risk allocation mechanism is such that all individual agents fully insure their individual risks, but an additional payment (or a reimbursement) to (from) the insurer has to be payed (or will be payed) according to the total loss of the insurance pool! To go further, one has to know the mathematical structure of the loss correlations. Different mathematical structures (e.g. whether the components are additively or multiplicatively connected) perhaps deserve *different* markets and different contracts to arrive at an optimal risk allocation (Doherty and Schlesinger 2002, p. 47). Very interesting here is that—with the approach of Doherty and Schlesinger—the individual agent can determine by herself the degree of participation (or coverage) of the total loss (or of the non-diversifiable part). Without going into (mathematical) details, a special result should be retained:

> If the market risk premium is identical for the systematic risk,whether traded on a futures or an insurance market,[11] then the *mutual insurance market* delivers the same set of alternatives and the same optimal solutions as can be expected on *two separate markets*, i.e. one insurance and one capital market!

One caveat that should not be passed over is associated with the preferences of insurance buyers: in the mutual contract the total premium has to be paid in advance, or *ex ante*, while the actual premium to be paid depends *ex post* on the realised value of the 'systematic component'. To a degree, the *timing* of the premium payment and indemnity payment plays a role. More to the point, *mutual insurance contracts* allocate the risks *ex post*, while 'traditional' insurance contracts allocate them *ex ante* by fixed premiums. Furthermore, mutual insurance contracts can—theoretically—entail a high additional payment for the insured.[12] However, the 'insurance pool' or

[10] For a summary, see Zweifel et al. (2021).

[11] As shown by Froot (2001), it is possible to take into account that advantages in transactions costs can exist compared to 'traditional' insurance products.

[12] In a mathematical context this question is taken up by Albrecht and Huggenberger (2017) in footnote 20, p. 183.

'insurance association' can 'incorporate' a large part of these premium adjustments as part of the insurance premium, and can invest in an 'equalisation fund' for intertemporal smoothing!

Macroeconomic risks (demographic risks in particular)

A final example of the importance of distinguishing between *mutuality theory* and *reserve theory* relates to macroeconomic risks or, in particular, to demographic risks.

Skogh (1999) highlighted collective solutions via the state, in particular with interdependent and/or very large losses;[13] first, because the 'national pool' is very large, as pointed out by Arrow and Lind (1970); second, because if such risks are almost not foreseeable or are in principle unforeseeable, a collectively organised allocation over all members of the state can be advantageous "as long as the presumption of uncertainty is actually accepted" (Skogh 1999, p. 513). This may be denied for demographic risks. Herwig Birg, a German demographer, emphasised that long-run demographic prognoses are rather accurate because of the great influence of age on the number of births and deaths and—in medium range—less on reproductive behaviour (Birg 2006). Nevertheless, the different variants of the 14th coordinated population projection differ widely according to assumptions about life expectancy, immigration, death and birth rates etc. The German Statistical Office (2019) calculates a population for Germany in 2050 between 77.5 million with Variant 1, up to 84.4 million with Variant 9 and 83.6 million with 'moderate development'. All in all, this is a dispersion of 6.9 million.[14] It is, however, important to develop "a dynamic stochastic model …that captures *historical* deviations from the model" for every component (see Anderson et al. 2001, p. 10). Further, it is important to take into account the long-run 'wave character' of demographic development. This is meant when one speaks of the ageing process as a 'temporary phenomenon', because a great 'baby boom cohort' is followed by a small 'pill break generation', as formulated by Börsch-Supan (1999, p. 29).

Macroeconomic shocks and non-diversifiable risks cannot be eliminated by 'traditional' portfolio or hedging strategies. As Allen and Gale (2000, p. 155) observe, these strategies deliver only 'cross-sectional risk sharing', i.e. a risk exchange between agents at a fixed point in time. Long-run risks—as in long-run contracts or demographic changes—need intertemporal risk smoothing, either a capital stock (with all the well-known problems, see e.g. Orszag and Stiglitz 2001 on the 10 myths of social security systems),[15] or an intergenerational risk allocation. For this,

[13] According to the above argument, his statement "if a risk is actuarial and thus insurable it may be reinsured and diversified world-wide via financial markets" (Skogh 1999, p. 513) is not very convincing.

[14] Looking at the 10th coordinated population projection (see Sommer 2003), the figures are even more pronounced, lying between 67 and 81 million with a 'mean' around 75 million. This gives a dispersion of 14 million people!

[15] It is not intended here to discuss at length the advantages or disadvantages of public debt (especially in a low interest rate setting), but see e.g. the book by von Weizsäcker and Krämer (2019) or Blanchard (2019) in his presidential lecture.

one needs specific institutions, e.g. a collective social security system (see Eisen 2004a and Demonge and Laroque 2000). Only the state is able to newly allocate or reallocate such risks via changing its debt policy or via taxes and subsidies. However, an innovative debt policy is in order, because differently indexed securities or bonds generate different risk allocations (see Bohn 2002). For example, a sure public debt implies that the fluctuation of the consumption of retired people will be reduced, but the effects of productivity or demographic shocks for the working generation will be increased or their consumption will be more volatile! A wage-indexed pension guarantees a fixed wage or income replacement rate; however, now the premium rate fluctuates with demographic development (but not with macro-economic shocks)! The alternative, however, as favoured here, is *mutual insurance*, which seems the appropriate way to cope with increasing vulnerability!

Summary

Increasing vulnerability, which preoccupied Orio Giarini (Giarini 1977) calls for a new economic theory that can take into account the dynamic trends of growing dimensions of both types of risks, either human-made or natural disasters or pure risks. The higher the level of vulnerability, the more interrelated are the two types of risk, combined with increasing concentration and the trend toward a service economy. I tried not to develop this new economic theory, but to stress the fact that insurance has its roots in mutual insurance.

In insurance, two types of property rights structures are well-known: the share company and the mutual association. While the mutual association belongs to its insurance buyers, the share company is owned by the shareholders, who need not sign insurance contracts with this company.[16] These different forms of organisation are connected with different assignments of property rights and with different (contract) costs: if transactions, contracts or control costs would be negligible, then no form of organisation would be preferable. Fama and Jensen (1983), however, have argued that, with high probability, mutual insurers exist if (1) the costs of increasing or decreasing of assets and (2) the costs of producing exact indices of the value of assets are small. Since insurers hold financial assets in particular, these two conditions describe the insurance industry very well.

In this paper, I show that these structural differences are well-founded. Furthermore, I point out the resulting differences in risk allocation, which only disappear if the law of large numbers is valid and the insurance markets are perfect and complete.[17] These conditions are (normally) not fulfilled; therefore, there also exists a 'practical' difference.

After developing some basic theory about the difference between the traditional *reserve theory of insurance* and the *pure mutuality theory of insurance*,

---

[16] There are also public insurers, which can be organised or structured in a different way, according to public law.

[17] See also Eisen (2004b).

three examples are discussed and the advantages of the mutuality theory are clearly shown: unknown probabilities connected with unforeseeable events, correlated risks and macroeconomic or demographic risks. Two questions are, however, still unresolved: First, whether the alternative via ‘securitisation’ using the capital market (i.e. using two markets, the insurance market for the diversifiable part and the capital market for the non-diversifiable part of the risks) is cheaper or more costly than the ‘participating’ mutual contract. Second, whether the insurance buyers (or members of the mutual association) are risk averse and will prefer the more expensive traditional mechanism and therefore shrink back from the risk of the (maybe very high) additional payment.

Funding Open Access funding enabled and organized by Projekt DEAL.

References

Albrecht, P., and M. Huggenberger. 2017. The fundamental theorem of mutual insurance. *Insurance: Mathematics and Economics* 75: 180–188.

Allen, F., and D. Gale. 2000. *Comparing financial systems*. Cambridge: MIT Press.

Anderson, M.S., S. Tuljapurkar, and N. Li. 2001. How accurate are demographic projections used in forecasting pension expenditures? In *Pensions: More information, less ideology*, ed. T. Boeri, et al., 9–27. Boston: Springer.

Arrow, K.J. 1970. *Essays in the theory of risk bearing*. Amsterdam and London: North-Holland.

Arrow, K.J., and R.C. Lind. 1970. Uncertainty and evaluation of public investment. *American Economic Review* 60: 364–378. (Reprinted in Arrow 1970, 239–266.)

Beard, R.E., T. Pentikäinen, and E. Pesonen. 1984. *Risk theory*. London: Chapman and Hall.

Birg, H. 2006. Unser Verschwinden würde nicht auffallen - vierzehn Richtigstellungen von dreizehn Legenden über die demographische Entwicklung Deutschlands. *Frankfurter Allgemeine Zeitung* 147: 44.

Blanchard, O. 2019. Public debt and low interest rates. *American Economic Review* 109 (4): 1197–1229.

Bohn, H. 2002. Retirement savings in an ageing society: A case for innovative government debt management. In *Ageing, financial markets and monetary policy*, ed. A.J. Auerbach and H. Hermann, 139–181. Berlin: Springer.

Borch, K. 1974. *The mathematical theory of insurance*. Lexington: D. C. Heath, Lexington Books.

Borch, K. 1990. *The economics of insurance*. Amsterdam: North-Holland.

Börsch-Supan, A. 1999. Demographische Entwicklung und Stabilität der Sozialversicherung in Deutschland. *Allgemeines Statistisches Archiv* 83: 27–44.

Bourlés, R. 2008. *Essais sur la stabilité des accords d’assurance mutuelle. Thèse pour le doctorat en sciences economiques, Université Aix-MarseilleII*.

Crockford, G.N. 1976. The changing face of risk management. *The Geneva Papers on Risk and Insurance* 1 (2): 10–15.

Demonge, G., and G. Laroque. 2000. Social security, optimality, and equilibria in a stochastic overlapping generations economy. *Journal of PublicEconomic Theory* 2: 1–23.
Doherty, N.A. 1984. Portfolio efficient insurance buying strategies. *Journal of Risk and Uncertainty* 4: 205–224.
Doherty, N.A., and H. Schlesinger. 2002. Insurance contracts and securitization. *Journal of Risk and Insurance* 69: 45–62.
Eisen, R. 1979. Equilibrium in risk bearing: Different implications of alternative interpretations. *The Geneva Papers on Risk and Insurance* 11: 14–33.
Eisen, R. 2004a. Zeitpunktbezogene vs intertemporale Risikoteilung - ein Beitrag zur Diskussion von Umlage- und Kapitaldeckungsverfahren. In *Risikoforschung und Versicherung, Festschrift für Elmar Helten*, ed. P. Albrecht, et al., 65–90. Karlsruhe: Verlag Versicherungswirtschaft.
Eisen, R. 2004b. Incomplete markets. In *Encyclopaedia of actuarial science.* Wiley.
Eisen, R. 2006. Zu den zwei Versicherungsbegriffen von Werner Mahr und ihrer Bedeutung in der heutigen Zeit. *Zeitschrift für die gesamte Versicherungswissenschaft* 95: 581–595.
Fama, E.F., and M.C. Jensen. 1983. Agency problems and residual claims. *Journal of Law and Economics* 6: 327–349.
Froot, K.A. 2001. The market for catastrophe risk: A critical examination. *Journal of Financial Economics* 60: 529–571.
Gatzert, N., and H. Schmeisser. 2012. The merits of pooling claims revisited. *Journal of Risk and Finance* 13: 184–198.
Giarini, O. 1977. Economics, vulnerability and the diminishing returns of technology. *The Geneva Papers on Risk and Insurance* 6 (4): 36–52.
Giarini, O. 1982. Développement economique et croissance des risques. *The Geneva Papers on Risk and Insurance* 7: 13–26.
Giarini, O., and H. Loubergé. 1976. *Introduction à l'economie du risque et de la sécurité, première partie: Macro-économie du risque et de la sécurité*. Etudes et Dossiers No. 3, Geneva.
Giarini, O., and H. Loubergé. 1978. *The diminishing returns of technology: An essay on the crisis in economic growth*. Oxford: Pergamon Press.
Malinvaud, E. 1972. The allocation of individual risks in large markets. *Journal of Economic Theory* 4: 312–328.
Marshall, J.M. 1974. Insurance as a market in contingent claims: Structure and performance. *Bell Journal of Economic and Management Science* 5: 670–682.
Marshall, J.M. 1976. Moral hazard. *American Economic Review* 66: 880–890.
Mayers, D. 1976. Non-marketable assets, market segmentation and the level of asset prices. *Journal of Financial and Quantitative Analysis* 11: 1–12.
Murray, R.H. 2012. The blame game. *Risk Management Newsletter No. 51.* The Geneva Association.
Orszag, P.R., and J.E. Stiglitz. 2001. Rethinking pension reform: Ten myths about social security systems. In *New ideas about old age security: Toward sustainable pension systems in the 21st century*, ed. R. Holzmann and J.E. Stiglitz. Washington: World Bank.
Radner, R. 1968. Competitive equilibrium under uncertainty. *Econometrica* 36: 31–48.
Skogh, G. 1998. Development risks, strict liability, and the insurability of industrial hazards. *The Geneva Papers on Risk and Insurance—Issues and Practice* 23: 247–264.
Skogh, G. 1999. Risk-sharing institutions for unpredictable losses. *Journal of Institutional and Theoretical Economics* 155: 505–515.
Sommer, B. 2003. Bevölkerungsentwicklung bis 2050. *Wirtschaft und Statistik* 8: 693–701.
Venezian, E.C. 1983. Risk, return, and the rate of regulation on property and liability insurance. *Journal of Insurance Regulation* 2: 98–124.
Von Weizsäcker, C.C., and H. Krämer. 2019. *Sparen und Investieren im 21. Jahrhundert. Die grosse Divergenz.* Wiesbaden: Springer Gabler.
Willet, A.H. 1901. *The economic theory of risk and insurance.* Republished by S.S. Hubner Foundation for Insurance Education. Homewood, Illinois: Irwin Publishing.
Zweifel, P., R. Eisen, and D. Eckles. 2021. *Insurance economics*, 2nd ed. Heidelberg: Springer.

About the author

Roland Eisen Professor Emeritus, was born in Stuttgart in 1941. He studied at Technical University Stuttgart and LMUniversity in München, gaining a Master's in Economics in 1965, Dr. oec. publ. in 1971, thesis title *Technical Progress and Economic Growth*, and Dr. rer. pol. habil. in 1977, thesis title *Insurance Market Equlibrium*. After working as Assistant Professor and Associate Professor at universities in Bamberg and Freising, he was appointed Full Professor at the Goethe University Frankfurt until his retirement in 2006. He has special interests in insurance economics, labour economics, economics of social insurance and health, as well as long-term care insurance.