Optimal Insurance Purchasing in the Presence of Compulsory Insurance and Uninsurable Risks

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1. Introduction

In most industrialized countries some individual risks are covered by compulsory insurance and social security schemes leaving only a relatively small segment for individual choices concerning the level of insurance demand. For example, almost 89% of total insurance premiums in West Germany are paid to finance compulsory private or social insurance coverage (cf. Schulenburg [1984]). Under the pressure of rapidly expanding social security expenditures and along the lines of the deregulation movements a restriction of statutory insurance requirements was proposed by politicians and economists. One might ask how the demand for (voluntary purchased) market insurance is influenced by the existence of compulsory insurance and how it and individual welfare will be affected by a decreasing level of compulsory insurance coverage. Unfortunately, the existing theory of insurance purchasing gives no answer to these questions because it does not take into account the presence of compulsory insurance and uninsurable risks.

The purpose of this paper is to fill this gap. However, before presenting and discussing the *multi-hazard* risk model we will briefly review the basic approach and results derived from the traditional *one-risk* model. It assumes risk-averse expected utility maximizing individuals. Every individual has one given risk¹ which can be insured by one insurance policy.² The individual is free to choose the level and form of insurance coverage. This model leads to the following well-known results³:

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Research for this paper has been supported by the Swiss National Science Foundation (Grant No. 4.349-0.79.08). That support and helpful comments from H.E. Frech III, Paul R. Kleindorfer, Harris Schlesinger, Hans Möller and two anonymous referees on an earlier draft of this paper are gratefully acknowledged.

¹ The basic model considers a world with given loss probability distributions, i.e. the random income cannot be affected by individual loss prevention efforts or moral hazard behavior. See e.g. Ehrlich/Becker [1972] and Shavell [1979].

² In the absence of transaction and information costs all insurers offer the same policy. See for the case that information is costly and losses vary with individual prevention efforts Pauly [1974], Stiglitz [1973].

³ cf. Arrow [1963, 1974], Pashigian/Schkade/Menefee [1966], Mossin [1968], Smith [1968], Sandmo [1969], Hoffländer/Renshaw [1971], Borch [1975], Kunreuther [1976], Moffet [1977], Cook/Graham [1977].

- If an individual is risk averse, and the premium exceeds the expected insurance benefits (= net premium) by a proportional or risk-dependent loading-factor,⁴ it is suboptimal to buy full insurance coverage against a given risk, i.e. the individual will choose a cost-sharing arrangement.
- A risk averse individual will buy full insurance coverage or no insurance coverage at all if the loading factor is fixed, i.e. is independent of the volume of insurance coverage bought by the individual.
- If the loading factor is proportional to the expected insurance benefits, a deductible will be the optimal costsharing arrangement from the individual point of view.
- If both the insurer and the insuree are risk-averse, and if there are no other costs than those to cover the losses caused by a risk, only a reciprocal co-insurance contract will satisfy the conditions of a Pareto optimal allocation (cf. Borch [1974], Bühlmann/Gerber [1978]).

Our analysis will mainly focus on the first proposition, which is in contradiction to the widespread use of full insurance contracts. We will show that this proposition is valid only under restrictive assumptions and has to be modified in the presence of social or compulsory insurance schemes and uninsurable risks (cf. for the latter Doherty/Schlesinger [1983b]).

2. The multi-hazard risk model

As mentioned above, the traditional model framework for analysing the properties of optimal insurance coverage assumes *one* risk (which randomizes income) and *one* insurance against that risk. In addition, it implicitly proceeds from the assumption that in principle the total risk of the considered individual is insurable, i.e. can be ceded on insurance markets by paying a given premium. In reality, however, we have many different insurance markets for different risks. Some parts of the risk have to be covered by social security schemes and compulsory insurance (e.g. liability insurance). Other parts may be covered by purchasing market insurance, and some types of risks are not insurable at all (so called uninsurable risks). This separation of the individual risk is due to many reasons. Firstly, checking claims and controlling individual attempts to prevent losses cause information and transaction costs. Insurance companies, therefore, try to lower these costs by forming risk-groups and tariff classes implying a segmentation of existing risks. Secondly, in some countries a separation of the insurance business by type of risk (e.g. life, health, liability insurance) is prescribed by law. Thirdly, moral hazard and adverse selection processes cause the uninsurability of some risks, e.g. the entrepreneurial risk or the thief's risk of being caught by the police seem to be uninsurable risks.

⁴ The price for insurance, i.e. the gross-premium, consists of two components, the net premium which is equal to the expected insurance benefits and a loading covering the insurer's administrative costs and compensating the insurer for taking over risks.

In the following we will develop a simple *multi-hazard* risk model to analyse the interdependencies of compulsory insurance directions, the existence of uninsurable risks, and the demand for market insurance. For simplicity we will employ the common mean variance approach.⁵

Assume a risk-averse individual with the following objective function

$$(1) \quad \max U(EY, VY) \text{ with } U_{EY} > 0 > U_{EY EY} \quad U_{VY} < 0.$$

where EY and VY are the mean and the variance of the income Y .

We assume further that the income consists of two random components, L and W . Throughout the paper we will consider L to be labor income and W to be the non-labor income realized from wealth. This is only taken for illustration. The initial situation (without insurance) is characterized by

$$EY = EL + EW,$$

$$VY = VL + VW + 2\text{Cov with Cov} = E \left[(L-EL) (W-EW) \right].$$

The sign of the covariance Cov between the two income components depends on the direction of association between L and W . If there is a positive (negative) association – that is, if small values of L tend to be associated with small (large) values of W and large values of L with large (small) values of W – then the covariance will be positive (negative). Note that both Cov = 0 and Cov = $-(VL+VW)/2$ are extreme cases. The first one implies that L and W are uncorrelated. In the second case VY is zero although L and W may be random variables.

Now, let us assume two insurance markets, one for the labor income and one for the non-labor income risk, where coinsurance contracts are offered. That is, the insurance benefits are given by

$$BL = l (L^{\max} - L),$$

$$BW = w(W^{\max} - W) \text{ with } l \geq 0, w \geq 0$$

l and w denote the extent of insurance coverage, $L^{\max} + W^{\max}$ the maximum attainable income and $(L^{\max} - L)$ and $(W^{\max} - W)$ are, therefore, the “losses”, if the labor income and non-labor income are L and W , respectively. If $l = 1$ and $w = 1$, then the total losses are covered by insurance, i.e. full insurance coverage is provided by both policies.

⁵ For a broader discussion about the conditions under which the mean-variance approach may be used as a proxy for the more general expected utility criterion see Borch [1974], p. 384, Hakansson [1971], Levy/Markowitz [1979] and Sinn [1983]. Sinn concludes from his study: “In majority cases ... despite views to the contrary expressed occasionally by some authors, there is no justification for claiming a higher degree of generality for the expected-utility approach than for the (mean-variance) approach”, p. 120. The mean-variance approach is also employed by Mayer/Smith [1983] and Doherty [1984] to show the conditions under which full coverage is optimal if risks are separated. The contribution by Mayer/Smith [1983] is extended by Buser/Smith [1984].

The insurance premiums are calculated on an actuarial basis with proportional loading factors α and β

$$PL = EBL (1 + \alpha), \quad \alpha \geq 0,$$

$$PW = EBW(1 + \beta), \quad \beta \geq 0,$$

where EBL and EBW are the expected insurance benefits.

$$EBL = l (L^{\max} - EL),$$

$$EBW = w(W^{\max} - EW).$$

We obtain for the expected income and its variance *with* insurance coverage

$$(2) \quad EY(l, w) = EL(1 + \alpha l) + EW(1 + \beta w) - \alpha l L^{\max} - \beta w W^{\max}$$

$$(3) \quad VY(l, w) = VL(1) + VW(w) + 2\text{Cov}(l, w).$$

Notice that $VY(l, w)$, $VL(l)$, $VW(w)$, and $\text{Cov}(l, w)$ are now dependent on the extent of insurance coverage so that $VY(0, 0) = VY$ and $VY(1, 1) = 0$. Obviously, the expressions in (3) have the following properties⁶:

$$VL(l) = (1-l)^2 VL,$$

$$VL(l)_l = -2(1-l)VL < 0 \quad \text{if } l < 1,$$

$$VL(l)_{ll} = 2VL > 0,$$

$$VL(l)_{lll} = 0,$$

and analogous

$$VW(w) = (1-w)^2 VW,$$

$$VW(w)_w < 0 \text{ if } w < 1. \quad VW(w)_{ww} > 0, \quad VW(w)_{www} = 0,$$

and

$$\text{Cov}(l, w) = (1-l)(1-w) \text{Cov}$$

$$\text{Cov}(l, w)_l = -(1-w) \text{Cov}, \quad \text{Cov}(l, w)_w = -(1-l) \text{Cov}$$

$$\text{Cov}(l, w)_{ll} = 0, \quad \text{Cov}(l, w)_{ww} = 0,$$

where VL , VW , and Cov are the variances of L and W and the covariance when $l = w = 0$.

⁶ Subscripts denote partial derivatives.

3. Optimal insurance coverage

First, we will consider the case without regulatory demand directions so that the individual is free to choose the extent of insurance coverage and the co-insurance rates, respectively. The optimal insurance demand is then given by choosing l and w to maximize (1) subject to (2) and (3). First order conditions for a maximum are⁷:

$$(4) \quad U_{EY} \alpha(EL - L^{\max}) + U_{YY}(VL(l^*, w^*)_l + 2\text{Cov}(l^*, w^*)_l) = 0$$

$$(5) \quad U_{EY} \beta(EW - W^{\max}) + U_{YY}(VW(w^*)_w + 2\text{Cov}(l^*, w^*)_w) = 0$$

These conditions lead to

Proposition 1: If the premium is actuarial fair (i.e. the loading factor is zero) and the covariance between the considered risk and other risks is zero, full coverage is optimal (see also Doherty/Schlesinger [1983a]).

To prove Proposition 1 imagine $\alpha = 0$. Then (4) becomes $VL(l^*)_l + 2\text{Cov}(l^*, w^*)_l = 0$. The first term is zero, iff $l^* = 1$, i.e. full insurance coverage is optimal. The second term will only be zero if the other risk is fully insured ($w^* = 1$) and/or L and W are uncorrelated. Therefore, we can specify Proposition 1 as follows:

Proposition 1a: Full coverage is optimal if the premium is actuarially fair and the considered risk is uncorrelated with other risks.

Proposition 1b: Full coverage is optimal if the premium is actuarially fair and those risks are fully insured which are correlated with the considered risk.

Proposition 1c: If the premium is actuarially unfair (i.e. the loading factor is positive) and the considered risk is uncorrelated with other risks, then it is optimal not to buy full insurance coverage, that means to buy a cost-sharing contract.

The conclusions drawn from the traditional one-risk model prove to be a special case for Proposition 1 derived from a multi-hazard model. In addition we may follow from (4) and (5):

Proposition 2: Even if the premium is actuarially fair, it may be optimal to buy no insurance coverage at all.

If, for example, $\alpha = 0$ and $l^* = 0$, then we obtain for (4) (remember the properties of (3))

$$VL = -(1 - w^*) \text{Cov}$$

If the left hand side is equal or less than the right hand side, the individual will not seek to insure himself against the labor-income risk. Obviously this case will occur only if the risks are negatively correlated ($\text{Cov} < 0$). In other words, insurance is irrelevant when the individual has the opportunity to balance his or her portfolio perfectly. The “hedging” is homemade.

⁷ A star denotes an optimal value. A cross marks that the parameter is set by a regulatory measure.

Proposition 3: If the loading-ratio is one ($\alpha(L^{\max} - EL) = \beta(W^{\max} - EW)$) and the variances of the different risks are the same ($VL = VW$), then the optional coinsurance rate will be the same for every insurance contract.

By substituting (4) into (5) we obtain (if $\beta \neq 0$)

$$(6) \quad \frac{\alpha(L^{\max} - EL)}{\beta(W^{\max} - EW)} = \frac{VL(l^*)_l + 2\text{Cov}(l^*, w^*)_l}{VW(w^*)_w + 2\text{Cov}(l^*, w^*)_w}$$

which may be called the efficiency equation of insurance protection because it is independent of the specific form of the utility function (see also theorem 5 in Doherty [1984]). In the optimum the loading or price ratio has to be equal to the ratio of the marginal variance reducing effects of insurance. From (6) follows $l^* = w^*$ if the left hand side of the equation is one and $VL = VW$.

4. Compulsory insurance coverage and the demand for market insurance

Now we will turn to the case that the demand for insurance-protection against one risk is directed by law. Assume, for example, that against the non-labor income risk a co-insurance rate w^* is prescribed by law.⁸ How does such a regulation affect other insurance markets, such as the one for labor income risks?

To give an answer, let us consider equation (4) for a given w^* . This will lead us to two propositions:

Proposition 4: Statutory required insurance demand may lead to a situation where it is optimal to overinsure on other insurance markets even if the premium is unfair. In such a case additional regulations prohibiting the purchase of overinsurance coverage may lead to additional welfare losses.⁹

This is the same thing as saying that $l^* > 1$ or $VL(l^*)_l > 0$. From (4) we know that this might only occur if

$$VL(l^*)_l = -U_{EY}/U_{YY} \alpha(EL - L^{\max}) - 2\text{Cov}(l^*)_l > 0$$

or

$$\text{Cov} > \frac{U_{EY}/U_{YY} \alpha(EL - L^{\max})}{2(1 - w^*)}.$$

If the premium is fair ($\alpha = 0$) and $w^* < 1$, the condition becomes $\text{Cov} > 0$.

⁸ Note, that if w^* would be a compulsory minimum level of insurance then the insuree would wish to buy additional insurance coverage against the W -risk if w^* is too low. Here we assume for simplicity that w^* is given and additional insurance coverage for the w -risk is not available.

⁹ For example, in Germany overinsurance is prohibited by law, see § 1 VVG and the comment by Prölss/Martin [1973], 38. Notice that we assume a given probability distribution which cannot be influenced by individual action. If we take into consideration, for instance, loss prevention and moral hazard the conclusions presented in this paper have to be modified.

Proposition 5: The optimal demand for insurance against a given risk will decrease with an increase of statutory insurance requirements against other risks if the covariance between the risks is positive or not too negative.

Assuming for simplicity $U_{VYVY} = 0$ and differentiating (4) with respect to l^* and w^* we obtain

$$(7) \quad \frac{dl^*}{dw^*} = - \frac{\overset{<0}{U_{EY EY}} \alpha \overset{<0}{\beta} (EL - L^{\max}) (\overset{<0}{EW} - W^{\max}) + \overset{<0}{U_{VY}} 2 \overset{?}{Cov}}{\overset{<0}{U_{EY EY}} \alpha^2 \overset{>0}{(EL - L^{\max})^2} + \overset{<0}{U_{VY}} 2 \overset{>0}{VL}}$$

dl^*/dw^* will be negative if $Cov > 0$ or not that negative that it will overcompensate the first expression of the nominator.

To find out how the welfare is affected by an increase of compulsory insurance coverage, we differentiate (1) with respect to w^* :

$$(8) \quad \frac{dU}{dw^*} = \overset{(a)}{U_{EY} \alpha (EL - L^{\max})} + \overset{(b)}{U_{VY} (VL(l^*)_l + 2Cov(l^*, w^*)_l)} \frac{dl^*}{dw^*} + \overset{(c)}{U_{EY} \beta (EW - W^{\max})} + \overset{(d)}{U_{VY} (VW(w^*)_w + 2Cov(l^*, w^*)_w)}$$

The individual will gain from an increase of compulsory insurance coverage if (8) is positive. He or she will suffer welfare losses if (8) is negative. Therefore we may follow two propositions:

Proposition 6: If all insurance premiums are fair and (the absolute value of) the covariance between the risks is equal to the variance of each risk, then an increase of compulsory insurance coverage will not affect the individual's welfare.

That is, if $\alpha = \beta = 0$ and $-Cov = VL = VW$. In this case the terms (a) and (c) in (8) are zero and $(VL(l^*)_l + 2Cov(l^*, w^*)_l) = (VW(w^*)_w + 2Cov(l^*, w^*)_w)$. In addition, (7) tells us that $dl^*/dw^* = -1$. The increase of compulsory insurance coverage can be totally compensated by a decrease of insurance demand on the unregulated market.

If $-Cov = VL = VW$, the individual bears no risk at all in the initial situation. An increase in statutory insurance coverage will induce additional insurance demand on the free insurance market to neutralize the risk increasing effect of the compulsory insurance coverage. Because insurance coverage is costless, as the insurance premiums are equal expected costs ($\alpha = \beta = 0$), the individual will suffer no welfare losses by the compensatory transactions on the unregulated insurance market.

Proposition 7: If the loadings are equal for compulsory insurance coverage and insurance coverage on the unregulated market, and the covariance between the risks is equal to the variance of each risk, then the welfare of the individual will not be affected by an increase in compulsory insurance coverage, as long as $l^*(w^*) > 0$.

This is the same as saying that $\alpha(EL - L^{\max}) = \beta(EW - W^{\max})$ and $Cov = VL = VW$. Hence, $dl^*/dw^* = 1$ and (a) = (c) in (8). However, as we may easily derive from (4), $l^* + w^* = z^* < 2$ and z^* is a constant value. Therefore, if w^* becomes larger than z^* , l^* will be zero and the individual will suffer a welfare loss by an increase of compulsory coverage.

Figure 1: Welfare effects of compulsory insurance coverage

w^+ = compulsory insurance coverage

l^* = optimal demand for other insurance coverage

U = welfare level

Proposition 8: If the compulsory coverage is larger than the optimal one, the individual will enjoy a welfare gain by a decrease in compulsory insurance coverage.

In other words, if $w^* > w^*$, then $dU/dw^* < 0$. As we know from the first and second order conditions for a maximum (a) and (b) as well as (c) and (d) in (8) must not only be zero for l^* and w^* but also have to be a decreasing function in l and w . Therefore, (c) and (d) will be negative for $w^* > w^*$, and (a) must have the opposite sign to (b). Figure 1 illustrates propositions (6) to (8). For different specific premium calculation modes and relationships between the considered risks the upper diagram shows how the insurance coverage would be chosen for the L -risk (l^*) if the extent of insurance coverage for the W -risk is given by law (w^*). The lower diagram indicates how individual welfare will be affected by an increase of w^* . In those cases where the U -curve is negatively shaped individual welfare would be increased by lowering the w^* requirements.

5. Optimal insurance coverage in the presence of uninsurable risks

Within the framework of multi-hazard risks it is easy to derive how well-known propositions about optimal insurance-purchasing strategies have to be changed if we are confronted with uninsurable risks. It is easy to find examples for those risks which cannot be covered on insurance markets. If the non-labor income risk is, for example, an uninsurable risk we simply solve (4) for l^* assuming $w^* = 0$. This is because uninsurable risks can be thought of as a special case where the compulsory insurance is zero, i.e. $w^* = 0$. l^* is then given by

$$(9) \quad 1-l^* = \frac{U_{EY} \alpha(EL-L^{\max}) - U_{YY} 2Cov}{U_{YY} 2VL}$$

Obviously l^* is greater than one if the right hand side of (9) is negative. this leads to:

Proposition 9: Even if the premium is unfair ($\alpha > 0$), it may be optimal to buy more than full coverage if the considered risk and the uninsurable risk exhibit positive correlation.

Proposition 10: If the premium is fair ($\alpha = 0$), it is always optimal to buy more or less than full insurance coverage if the correlation is positive or negative, respectively.

If $\alpha = 0$ we obtain from (9)

$$1-l^* = -Cov/VL$$

so that $Cov \geq 0$ implies $l^* \geq 1$.

6. Conclusions

We have demonstrated in a simple model framework that the existence of social security schemes or compulsory insurance directions and the presence of uninsurable risks have a strong influence on individual welfare and the demand for market insurance. Well known

theorems concerning optimal insurance purchasing which are derived from the traditional *one-risk* model are special cases of those derived from the more realistic *multi-hazard* model presented in this article. In the presence of compulsory insurance and uninsurable risks it is generally no longer true that rational behaviour implies purchasing full insurance coverage for a certain risk if the premium is fair or that full coverage and overinsurance is suboptimal if the premium is unfair. Our model shows that only in special cases an increase of compulsory insurance requirements will not lower the demand for market insurance and decrease individual welfare. Only if compulsory insurance is subsidised by a third party, the individual will suffer no welfare loss.

Neither the traditional studies on optimal insurance demand by Arrow [1963], Mossin [1968], Smith [1968] and others questioned why there is an insurance demand at all; nor did we. Those studies hide implicitly the assumption that risks cannot be diversified away by a portfolio diversification à la Markowitz [1952]. More attention should be paid to this aspect when one considers the setting in which the modern theory of finance has developed (see e.g. Fama/Miller [1972]): in a world where the market place is without friction there is no need for insurance. Therefore, the existence of a demand for insurance can only be explained by some market imperfections such as transaction costs. These costs are, however, relevant for risks concerning human capital, as was already referred to in our model. In that case insurance appears to be the less costly device to cover that residual risk. In addition, compulsory insurance requirements lead inevitably to insurance demand. Future studies should consider the effects of compulsory insurance not only on market insurance demand but also on individual portfolio management in general.¹⁰

Further theoretical and empirical research is necessary for a better understanding of the interdependencies between social or compulsory insurance schemes and private insurance markets. The existence of uninsurable risks as well as the origin of social insurance programs can be explained among other things by moral hazard and adverse selection processes which might prevent market insurers from offering insurance coverage against some risks. In our model we have assumed given loss-distributions. It would certainly be appropriate and fruitful to introduce into the multi-hazard-model moral hazard and besides insurance other risk management measures. In addition, the analysis should be extended to more than two risks, because an increase or decrease of compulsory insurance coverage and uninsurable risks will have diverse effects on different insurance markets. However, a more complex multi-hazard model might raise a lot of ambiguities when it comes to comparative statics analysis using the traditional Arrow-Pratt risk-aversion measures.¹¹

¹⁰ Dionne/Eeckhoudt [1984], for instance, analysed the demand for insurance in a consumption-savings model à la Sandmo.

¹¹ See Turnbull [1983] for a more detailed analysis of this point.

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