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Taxation, Insurance, and Precautionary Labor

Nick Netzer* Florian Scheuer†‡

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Abstract

We examine optimal taxation and social insurance with adverse selection in competitive insurance markets. In the previous literature, it has been shown that, with perfect insurance markets, social insurance improves welfare since it is able to redistribute without creating distortions. This result has been taken as robust to the introduction of adverse selection as this would only provide additional justifications for social insurance. We show, however, that adverse selection can weaken the case for social insurance compared to a situation with perfect markets. Whenever social insurance mitigates private underinsurance, it also causes welfare-reducing effects by decreasing precautionary labor supply and hence tax revenue. In addition, adverse selection may reduce the redistributive potential of social insurance. We illustrate our general results using different equilibrium concepts for the insurance market. Notably, we derive conditions under which a complete renunciation of social insurance is optimal and the government only relies on income taxation to achieve its redistributive objectives.

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*University of Konstanz, Department of Economics, Box D136, 78457 Konstanz, Germany. Email: nick.netzer@uni-konstanz.de.

†Massachusetts Institute of Technology, Department of Economics, E52-391, Cambridge, MA 02139, USA. Email: scheuer@mit.edu.

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1 Introduction

It is known since Mirrlees (1971) that the problem of taxation is fundamentally linked to asymmetric information between the government and workers. Only with the assumption that the government cannot observe individual productivities does the need for distorting income taxation arise. The contributions of Rothschild and Stiglitz (1976) and Wilson (1977) have shown that a similar issue makes the problem of equilibrium in competitive insurance markets a relevant question. If insurance companies cannot observe risk types, the resulting market allocation will not in general be efficient. With this article, we aim at providing a theory that ties together these two branches of information economics and at highlighting previously ignored interactions between distorting taxation, social insurance and imperfect insurance markets.

Our starting point are the existing models of taxation and social insurance, such as Rochet (1991), Cremer and Pestieau (1996) and Henriet and Rochet (2004). Using the assumption of perfect insurance markets, this literature has concluded that social insurance can be a useful instrument for redistribution as it evens out differences in private insurance premiums without causing distortions. This result has been taken as robust to the introduction of adverse selection, which would only constitute an additional justification for social insurance. Indeed, Wilson (1977) and Eckstein, Eichenbaum, and Peled (1985) have shown that the government might be able to Pareto improve upon the market allocation by introducing social insurance in an insurance market with adverse selection. The simple intuition that equity and efficiency effects complement one another as motivations for social insurance has therefore prevailed.

In this paper, we demonstrate that this reasoning is invalid. It ignores interdependencies that emerge when the models of taxation and of insurance markets are combined thoroughly. The link between the two strands is a theory of precautionary labor that we develop in section 2. We show that, under a broad range of reasonable assumptions, greater uncertainty leads individuals to increase their labor supply. In section 3, we use this result to demonstrate that adverse selection can weaken the case for social insurance compared to a situation with perfect markets. Social insurance might indeed work against the inefficiency of underinsurance. At the same time, however, individuals faced with less uncertainty will reduce labor supply, and hence tax revenues will decline. This negatively affects social welfare. Furthermore, with adverse selection it is no longer clear whether social insurance can redistribute income at all, as private premiums do not necessarily correspond to individual risks any more.

In section 4, we illustrate our general results using different equilibrium concepts for the insurance markets. Several insights can be drawn from these illustrations. Social insurance will alleviate the inefficiency of underinsurance in the Rothschild-Stiglitz framework but has negative effects in the labor market by reducing precautionary labor supply. This endorses the case for only partial social insurance or even for complete renunciation. If the equilibrium is of the Wilson pooling type, social insurance additionally looses its main potential for redistribution. In case of a Miyazaki-Wilson equilibrium, no positive efficiency effects of social insurance remain, while it still entails labor supply distortions and suffers from reduced redistributive power. In sum, we conclude that the case for social insurance is weakened by the presence of adverse selection in insurance markets irrespective of the equilibrium concept considered.

The most similar existing work is the contribution by Boadway, Leite-Monteiro, Marchand, and Pestieau (2006) who were the first to examine optimal taxation with adverse selection and ex-post moral hazard in insurance markets.[1] Based on Rothschild-Stiglitz separating equilibria they find the case for social insurance strengthened by market inefficiencies. However, while labor supply is chosen under uncertainty in our model, their results are based on the assumption that labor supply decisions take place *after* a possible damage has been realized. This reduces the impact of underinsurance on individual decisions to income effects. We do not want to eliminate the precautionary effects resulting from labor supply under uncertainty which play a crucial role in understanding the interaction between taxation and insurance.

2 Labor Supply under Uncertainty

In this section, we derive important results on labor supply under uncertainty that will be used in our model of taxation and social insurance. Making use of the insights of Kimball (1990), we establish a theory of 'precautionary labor'. While the theory of precautionary savings has received some attention,[2] the problem of labor supply under uncertainty is less explored. Eaton and Rosen (1979) and (1980), Hartwick (2000), Parker, Belghitar, and Barmby (2005) and Floden (2006) consider the case of endogenous labor with wage uncertainty. We do not model wage risk but an income independent risk to consumption. Labor supply is chosen *before* the risk is realized. This gives rise to the question whether risk induces people to work more or less than they would in case of certainty.[3]

[1] We refrain from analyzing moral hazard in this article.

[2] See Sandmo (1970), Abel (1988), and Kimball (1990).

[3] Similar effects appear in Stiglitz (1982). However, this contribution lacks the theoretical tools developed by Kimball (1990), which will allow for a very clear analysis of labor supply under uncer-

We restrict our attention to Bernoulli random variables that result from a possible damage D which occurs with probability p. Let $\theta(\beta)$ denote such a random variable, where $\beta \in [0,1]$ stands for the share of the damage that is insured. It can be used to vary both expected value $\mathrm{E}[\theta(\beta)] = p\,(1-\beta)D$ and variance $\mathrm{Var}[\theta(\beta)] = p\,(1-p)[(1-\beta)D]^2$ of the risk. Furthermore, as throughout the paper, an additively separable utility function $U(c,L) = u(c)+v(L)$ is assumed, where c denotes consumption and L denotes labor supply.[4] Denote the productivity of an individual by w. Firms observe w and pay wages according to marginal productivity such that earned income is wL. The individual receives an additional, exogenous and state independent income T.

The first order condition for labor supply L^* that maximizes expected utility in the presence of a given consumption risk $\theta(\beta_0)$ is

$$w\,\mathrm{E}\left[u'\left(wL^* + T - \theta(\beta_0)\right)\right] = -v'(L^*), \tag{1}$$

where E is the expectations operator.[5] To answer the question how risk affects labor supply, we examine the move from $\theta(\beta_0)$ to the risk $\theta(\beta)+(\beta-\beta_0)pD$, which constitutes a change in variance, leaving the expected value unaffected. We define the *equivalent precautionary premium* $\Psi(\beta_0,\beta)$ for such a move implicitly as follows:

$$\mathrm{E}\left[u'\left(wL^* + T - \theta(\beta_0) - \Psi(\beta_0,\beta)\right)\right] = \mathrm{E}\left[u'\left(wL^* + T - \theta(\beta) - (\beta-\beta_0)pD\right)\right]. \tag{2}$$

It has the following interpretation: The compensated change in insurance will have the same effect on the LHS of (1) and therefore on optimal labor supply as a lump-sum reduction of income by $\Psi(\beta_0,\beta)$. Both affect the optimality condition in the same way. Therefore, statements about the effect of risk on labor supply can be restated as income effects triggered by a decrease of income by Ψ.

Implicit differentiation of (2) yields a formulation for $\partial\Psi(\beta_0,\beta)/\partial\beta$. Most relevant is the evaluation of this derivative at $\beta = \beta_0$, which gives the income change that has the same effect on labor supply as a small change in insurance, starting from a situation with insurance β_0. We obtain

$$\left.\frac{\partial\Psi(\beta_0,\beta)}{\partial\beta}\right|_{\beta=\beta_0} = \left(-\frac{\Delta u''(.)/(1-\beta_0)D}{\mathrm{E}[u''(.)]}\right)\left(\frac{1}{2}\frac{\partial \mathrm{Var}}{\partial\beta}\right), \tag{3}$$

tainty in the following.

[4] We assume the function v to be at least twice and u at least three times differentiable. In addition, the standard conditions $u'(c) > 0$, $u''(c) < 0$, $v'(L) < 0$ and $v''(L) < 0$ are assumed to hold.

[5] The sufficient second order condition for a maximum is satisfied.

where $\Delta u''(.)$ is the difference of $u''(.)$ between consumption levels in case of no damage and damage, and $\mathrm{E}[u''(.)]$ is the expected value of $u''(.)$.

The first term in brackets on the RHS of (3) is the *generalized coefficient of absolute prudence* $\eta^G(\beta_0)$. As β_0 converges to 1, i.e. the examined situation converges to a situation without risk, the coefficient η^G converges to the prudence η as defined by Kimball (1990), which is simply the coefficient of absolute risk aversion for the function $u'(.)$, i.e. $\eta = -u'''/u''$. From (3) follow first implications for labor supply under uncertainty, which are summarized in the following lemma.

Lemma 1. *A marginal increase in insurance coverage from β_0, which is compensated by an actuarially fair premium adjustment, decreases labor supply if and only if $\eta^G(\beta_0) > 0$.*

Proof. By (3) and $\partial \mathrm{Var}/\partial\beta < 0$, the compensated increase in insurance has the same effect as an increase in income if and only if $\eta^G(\beta_0) > 0$. Next, with separable preferences, leisure is a normal good. Hence an increase in income decreases labor supply. □

Conversely, a higher labor supply will be the reaction to less insurance iff $\eta^G > 0$; the individual has a motive for *precautionary labor*. The size of η^G indicates how strong this motive is. A sufficient condition for $\eta^G(\beta_0)$ to be positive is that $u'''(.)$ is positive in the relevant range of consumption levels. This in turn is a necessary condition for constant or decreasing risk aversion, both in absolute and relative terms.[6] Therefore, under the common and realistic assumption of non-increasing risk aversion, precautionary labor effects do exist.

The results so far were derived for changes in risk that leave the expected damage unaffected. If this is not the case, changes in risk entail additional income effects. It is still useful to distinguish between pure risk effects via the variance and income effects via expected values.

Lemma 2. *The total effect of a marginal increase in β on labor supply can be expressed as*

$$\frac{\partial L^*}{\partial \beta} = \frac{\partial L^*}{\partial T}\left[pD - \frac{\partial \Psi}{\partial \beta}\right], \tag{4}$$

where $\partial L^*/\partial T < 0$ is the negative income effect and $\partial\Psi/\partial\beta$ stands short for the expression (3).[7]

[6] See Appendix A in Netzer and Scheuer (2005), an earlier version of this paper, for a proof.

[7] Throughout the rest of the paper, we stick to this convention, i.e. we write $\partial\Psi/\partial\beta$ for the expression (3).

Proof. In the appendix. □

First, higher coverage increases expected income by pD. This effect would vanish if an insurance premium were adjusted actuarially fairly. Second, the change in the variance has the same effect as a decrease of income by the premium Ψ that is raised by an increased insurance coverage β. As shown above, this premium will in general be negative.

3 Optimal Taxation and Social Insurance

3.1 The Model

This section derives conditions for optimal government policy in the presence of adverse selection in insurance markets. This is done without an explicit model of such market imperfections. We demonstrate in section 4 that different equilibrium concepts can easily be incorporated.

Our model setup is similar to Cremer and Pestieau (1996) and Boadway, Leite-Monteiro, Marchand, and Pestieau (2006). We consider a society that consists of N individuals described by two characteristics: their productivity and their probability of incurring a damage of size D. There are W different productivity levels w_i, $i = 1, ..., W$ and two damage probabilities p_j, $j = L, H$, with $p_L < p_H$. In what follows, the index i will always refer to productivity while j refers to damage probability. We denote the proportion of individuals in the population that have productivity w_i and damage probability p_j by n_{ij}. The population average of the risk probability is $\bar{p} = \sum_{i,j} n_{ij} p_j$. The average risk within productivity group i is $\bar{p}_i = (1/(n_{iL} + n_{iH})) \sum_j n_{ij} p_j$.

As commonly assumed in the theory of optimal taxation, the government maximizes the utilitarian objective. It can neither observe individual productivities nor damage probabilities but only knows the joint distribution of both characteristics. Hours worked are unobservable as well, so that taxes have to be conditioned on observable labor income and will be distorting. The tax schedule is restricted to a constant marginal tax rate τ and a lump-sum transfer T. In addition, the government can force the citizens to insure a share α of the possible damage. Such social insurance is financed by a uniform contribution $\bar{p}\,\alpha D$ by each individual. The remaining risk can be insured privately. The contract that individual ij purchases is denoted by $\mathcal{I}_{ij} = (\beta_{ij}, d_{ij})$, where β_{ij} is the privately insured share of the damage and d_{ij} is the premium.

The time structure is as follows. First, the government sets its policy $\mathcal{P} = (\tau, T, \alpha)$. Taking $\mathcal{P}$ as given, individuals simultaneously choose their labor supply and purchase their insurance contract $\mathcal{I}_{ij}$. They also pay taxes and social insurance contributions and receive the transfer. Finally, the damage occurs according to the given probabilities. After payments of social and private insurance, consumption takes place.

3.2 Optimal Government Policy

The timing of our model is such that individuals simultaneously choose their labor supply and a private insurance contract. For the sake of exposition, however, suppose for the moment that an individual's choice of insurance $\mathcal{I}_{ij}$ is fixed exogenously. Then optimal labor supply $L^*_{ij}(\tau, T, \alpha, \beta_{ij}, d_{ij})$ can be determined. It is implicitly defined by a standard first order condition that can be differentiated to obtain comparative static effects as shown in the proof of Lemma 2. In our notation, the derivative of L^*_{ij} with respect to α already includes the effect of the increase in the social insurance contribution $\bar{p}\,\alpha D$. By contrast, the derivative with respect to β_{ij} does not take into account a change in the premium. Where needed, the effect that accounts for such a change is marked with the letter A:[8]

$$\left.\frac{\partial L^*_{ij}}{\partial \beta_{ij}}\right|_A = \frac{\partial L^*_{ij}}{\partial T}\left[p_j D - \frac{\partial d_{ij}}{\partial \beta_{ij}} - \frac{\partial \Psi_{ij}}{\partial \beta_{ij}}\right]. \tag{5}$$

Substitution of L^*_{ij} into the expected utility function yields the indirect expected utility function $V^*_{ij}(\tau, T, \alpha, \beta_{ij}, d_{ij})$.

The actual private insurance contracts are endogenous and will depend on the specific equilibrium concept as illustrated in section 4. At this point, it is only necessary to emphasize that they will depend on the policy $\mathcal{P}$, i.e. $\beta_{ij} = \beta_{ij}(\tau, T, \alpha)$ and $d_{ij} = d_{ij}(\tau, T, \alpha)$. For the purpose of comparative statics w.r.t. the policy parameters, it will be convenient, however, to express the premium d_{ij} as a differentiable function of the coverage β_{ij}, i.e. $d_{ij} = d_{ij}(\beta_{ij})$. This is indeed possible for all equilibrium concepts that we will consider later. Functions that account for equilibrium effects are marked by two asterisks, i.e. $L^{**}_{ij}(\tau, T, \alpha) = L^*_{ij}(\tau, T, \alpha, \beta_{ij}(\tau, T, \alpha), d_{ij}(\beta_{ij}(\tau, T, \alpha)))$. Indirect utility $V^{**}_{ij}(\tau, T, \alpha)$ is defined analogously. With this notation and assuming

[8] It is assumed in this formulation that the premium d can be derived from the coverage β through a differentiable function, so that $\partial d_{ij}/\partial \beta_{ij}$ is well-defined. This will be further explained below.

no exogenous revenue requirement, the government's optimization problem is

$$\max_{T,\tau,\alpha} \sum_{i,j} n_{ij} V_{ij}^{**}(\tau, T, \alpha) \qquad \text{s.t.} \qquad \sum_{i,j} n_{ij} \left(\tau w_i L_{ij}^{**} - T\right) = 0. \tag{6}$$

Since our focus is on the optimal level of social insurance, we omit a derivation and discussion of the optimality conditions for the tax parameters in this article, but confine our attention to the optimality condition for α.[9] Assuming an interior solution, we derive the first order condition for α implied by problem (6) and transform it to obtain the following Proposition 1. We use two important concepts. The first is the "net social marginal valuation of an individual's income", b_{ij}, well-known from the theory of optimal taxation,

$$b_{ij} = \frac{1}{\gamma}\frac{\partial V_{ij}^*}{\partial T} + \tau w_i \frac{\partial L_{ij}^*}{\partial T}, \tag{7}$$

where γ is the Lagrange multiplier associated with the revenue constraint, whose optimal value equals the welfare value of a marginal increase in government revenues. b_{ij} captures the effect of an increased transfer T on the objective via the individual's utility and via the effect on the budget constraint through labor supply changes, both measured in terms of government revenues. In our model, government policy has additional effects on the objective via the insurance market equilibrium. Therefore, the concept of "net social marginal valuation of an individual's insurance", g_{ij}, is useful:

$$g_{ij} = \frac{1}{\gamma} \left.\frac{\partial V_{ij}^*}{\partial \beta_{ij}}\right|_A + \tau w_i \left.\frac{\partial L_{ij}^*}{\partial \beta_{ij}}\right|_A . \tag{8}$$

It captures the effect of a changing equilibrium contract via utility and via the budget constraint. With this notation, we have

Proposition 1. *The optimality condition for the level of social insurance α, assuming an interior solution, is given by*

$$Cov\left(b, \frac{\partial d}{\partial \beta}\right) = -\sum_{i,j} n_{ij} g_{ij} \left(1 + \frac{\partial \beta_{ij}}{\partial \alpha}\right). \tag{9}$$

Proof. In the appendix. □

Condition (9) generalizes the respective condition that was obtained by Cremer and Pestieau (1996) for perfect private insurance markets. In this case, it reduces to

[9] The complete analysis can be found in Netzer and Scheuer (2005), an earlier version of this paper.

$\text{Cov}(b,p) = 0$. Social insurance simply crowds out private insurance ($\partial\beta_{ij}/\partial\alpha = -1$) so that the term on the RHS becomes zero. On the other hand, premiums are actuarially fair and (9) therefore states that the population covariance between damage probability and marginal social valuation should be zero. This reflects that social insurance is a non-distorting means of redistribution. Increasing α redistributes from low to high risks and lowers the covariance between risk and marginal social valuation. The government should do this until no correlation remains and the potential of social insurance for redistribution is exhausted.

Condition (9) becomes an inequality if the optimal α is a corner solution. Indeed, with perfect markets, the optimal share of social insurance will always be one if high productivity individuals have lower damage probabilities, i. e. $\text{Cov}(p,w) < 0$, which is the empirically relevant case.[10] With full social insurance, individuals differ only in their productivity, so that high risk types will still have the higher marginal social valuation due to their productivity disadvantage. Hence, $\text{Cov}(b,p) > 0$ for all values of α and full social insurance is optimal. This leads us to the following Corollary of Proposition 1, which is the result by Cremer and Pestieau (1996):

Corollary 1. *If $Cov(p,w) < 0$ and private insurance markets are perfect, the optimal social insurance level is $\alpha = 1$.*[11]

Now consider the general version (9). Suppose first that private insurance premiums are still adjusted actuarially fairly if government policy changes the equilibrium coverage ($\partial d_{ij}/\partial\beta_{ij} = p_j D$). Even if the correlation between risk and social valuation is positive for all values of α, partial social insurance or even $\alpha = 0$ can be optimal if the RHS of (9) is positive. In particular, suppose that social insurance indeed increases overall coverage for underinsured individuals ($\partial\beta_{ij}/\partial\alpha > -1$). The often discussed *efficiency effect* of mitigating underinsurance is then present. It is captured by the first, positive term in g_{ij} (see equation (8)): underinsured individuals experience an increase in utility if their overall coverage grows and premiums are adjusted fairly at the margin. However, there is a second, negative term in g_{ij} which captures the *precautionary labor effect*: individuals will react to the reduction of risk by reducing labor supply, as shown in Lemma 1. Since this reduces the revenues from income taxation, it will negatively affect social welfare. When this effect dominates, the sign of g_{ij} is negative and the RHS of (9) becomes positive. The argument for

[10] See Henriet and Rochet (2004) for some empirical evidence.

[11] In fact, the government would want to set $\alpha > 1$ under these circumstances. We do not consider this possibility due to the moral hazard problems associated with overinsurance.

social insurance is then weakened by adverse selection compared to situations with perfect insurance markets.

Finally, the fact that the adjustment of the private premium to changes in coverage matters for the covariance in (9) points at the logic of redistribution via social insurance. It is not damage probability per se but the possible savings on private premiums that matter for redistribution. While both are the same if markets are perfect, risk and premium can diverge under adverse selection and substantially change the *redistribution effect* of social insurance. If, for example, all individuals pay the same premium in a pooling contract, the covariance in (9) is zero. In this case, there is no justification for social insurance from the point of view of redistribution.

4 Imperfect Insurance Markets

While the dependence of the insurance contracts $\mathcal{I}_{ij}$ on the policy parameters $\mathcal{P}$ has been left unrestricted so far, we now show how such relations emerge from endogenizing the insurance market equilibrium. We assume that insurance companies have no information on individual risks p_j but can observe the individual productivity levels w_i. This assumption is to keep our exposition as simple as possible since otherwise we would have to deal with a problem of two-dimensional adverse selection.[12] It allows us to divide the private insurance market into W sub-markets, one for each productivity level. Adverse selection in each of those markets can be modeled using a variety of game theoretic approaches. In the following, we demonstrate how the general optimality condition for social insurance (9) can be applied to the equilibrium concepts developed by Rothschild and Stiglitz (1976), Wilson (1977) and Miyazaki (1977).[13]

4.1 Rothschild-Stiglitz Separating Equilibria

We first consider separating equilibria as suggested by Rothschild and Stiglitz (1976) in each of the W private insurance markets.[14] High risks obtain full coverage at an individually fair premium, i.e. $\beta_{iH} = 1 - \alpha$ and $d_{iH} = p_H(1 - \alpha)D$. The low risks'

[12] See Netzer and Scheuer (2006) for an extension of the standard screening model to allow for two-dimensional heterogeneity. Transferring their results to the present case would take us away from the main purpose of this paper, however.

[13] A similar analysis (based on their different timing assumption for labor supply mentioned above) has been performed by Boadway, Leite-Monteiro, Marchand, and Pestieau (2006), who only consider Rothschild-Stiglitz equilibria. By applying the results of Proposition 1 to different models of adverse selection, we try to provide a more general analysis and to identify the robust effects.

[14] Existence of the Rothschild-Stiglitz equilibrium can actually be guaranteed by applying the modified equilibrium concept developed by Riley (1979).

equilibrium contract lies on the low risks' zero-profit line and is such that the high risks' incentive compatibility constraint is just binding.[15] Formally, β_{iL} solves

$$V^*_{iH}(\tau, T, \alpha, 1-\alpha, p_H(1-\alpha)D) = V^*_{iH}(\tau, T, \alpha, \beta_{iL}, p_L\beta_{iL}D). \tag{10}$$

Clearly, the low risks are underinsured, i.e. $\beta_{iL} < 1-\alpha$.

We first derive the net social marginal valuation of insurance, g_{ij}, for the different types. As all individuals pay an actuarially fair premium, the premium-adjusted effect of a changed equilibrium coverage on labor supply reduces to the pure precautionary effect

$$\left.\frac{\partial L^*_{ij}}{\partial \beta_{ij}}\right|_A = -\frac{\partial L^*_{ij}}{\partial T}\frac{\partial \Psi_{ij}}{\partial \beta_{ij}} < 0. \tag{11}$$

In addition, (11) completely vanishes for the high risks because $\partial\Psi_{ij}/\partial\beta_{ij} = 0$ at full insurance. Next, we need to examine

$$\left.\frac{\partial V^*_{ij}}{\partial \beta_{ij}}\right|_A = \frac{\partial V^*_{ij}}{\partial \beta_{ij}} - p_j D\frac{\partial V^*_{ij}}{\partial T}.$$

This is again zero for the high risks, a direct implication of the fact that they obtain their optimal fair contract. The low risks, however, derive positive utility from an increase in coverage with fair adjustment of the premium. This follows immediately from risk-aversion and the fact that they are underinsured. Hence we have the following net social marginal valuation of insurance for the two risks types:

$$g_{iL} = \frac{1}{\gamma}\left(\frac{\partial V^*_{iL}}{\partial \beta_{iL}} - p_L D\frac{\partial V^*_{iL}}{\partial T}\right) - \tau w_i \frac{\partial L^*_{iL}}{\partial T}\frac{\partial \Psi_{iL}}{\partial \beta_{iL}} \quad \text{and} \quad g_{iH} = 0. \tag{12}$$

It is zero for the high risks as they obtain their first-best contract. For the low-risk types, the two counteracting welfare effects of variations in insurance coverage discussed in section 3.2 are present. They benefit from additional coverage at a fair premium, but at the same time supply less labor due to reduced risk. This reduces tax revenue and therefore welfare. The overall sign of g_{iL} depends notably on the size of the coefficient of prudence.

To determine the optimal amount of social insurance, we need to know how it

[15]For this to hold, the single crossing property is required, which implies that the high risks have the steeper indifference curve in the (β_{ij}, d_{ij})-space at any given contract. This is always satisfied in the standard model with exogenous income. With endogenous labor supply, however, it may be violated as shown by Netzer and Scheuer (2005). We ignore this potential complication in this article. Netzer and Scheuer (2005) provide sufficient conditions for the single crossing property to hold even with endogenous labor supply.

affects the individuals' *overall* coverage. Clearly, as the high risks are always fully insured, social insurance simply crowds out their private insurance: $\partial\beta_{iH}/\partial\alpha = -1$. For the low risks, implicit differentiation of (10) reveals after some simplifications that $\partial\beta_{iL}/\partial\alpha > -1$ holds. A marginal increase in social insurance unambiguously increases their overall coverage. We summarize our results in the following Corollary of Proposition 1:

Corollary 2. *With Rothschild-Stiglitz equilibria on each of the W private insurance markets, the optimality condition for social insurance is given by*

$$D\;Cov(b,p) = -\sum_i n_{iL} g_{iL}\left(1 + \frac{\partial\beta_{iL}}{\partial\alpha}\right), \tag{13}$$

where g_{iL} is given by (12) and $1 + \partial\beta_{iL}/\partial\alpha > 0$ holds. Even if $Cov(p,w) < 0$, the optimal level of α is less than one if households are sufficiently prudent.

Indeed, social insurance redistributes income as in the case of perfect markets and additionally has positive effects by reducing underinsurance. The negative effect of reducing labor supply is present as well, however. If households are very prudent, this alone justifies interior levels of social insurance or even complete renunciation of a social insurance system.

4.2 Wilson and Miyazaki-Wilson Equilibria

To what extent do the results in the previous subsection depend on the underlying equilibrium concept? To answer this question, we examine two alternative concepts in this section, the Wilson pooling equilibrium and the Miyazaki-Wilson equilibrium. We confine ourselves to an intuitive discussion of the results.[16]

The concept going back to Wilson (1977) allows for the existence of a pooling equilibrium where both risk types choose the same contract. For each productivity group i, the Wilson pooling contract is the low risks' preferred contract on the zero profit line for the whole group. Hence, there are two fundamental differences to the Rothschild-Stiglitz separating equilibrium. First, the whole population is underinsured. Second, no individual pays an individually fair premium, but cross-subsidization from low to high risks occurs. The most important conclusion follows from this second difference. Clearly, social insurance is no longer able to redistribute between risks, as this

[16] For the case of the Wilson pooling equilibrium, the reader is again referred to Netzer and Scheuer (2005) for the complete analysis. The formal demonstration for the Miyazaki-Wilson equilibrium is available from the authors upon request.

is already achieved in the market. The only remaining redistributive effect is across productivity classes if they are characterized by different private insurance premia. Formally, the covariance in (9) is very small even for $\alpha = 0$, which considerably weakens the case for social insurance.

Under the Wilson pooling equilibrium, the effect of α on private coverage is indeterminate in general. The empirically relevant case seems to be less than complete crowding out, however.[17] Then, we find that high risks will unambiguously reduce their labor supply in response to increases in α, since both larger overall coverage and the more than fair premium affect their labor supply in the same direction. The effect is in general undetermined for the low risks but also negative if they are sufficiently prudent. In a reversal of our findings based on the separating equilibria, only the high risks derive a direct utility gain from increased coverage, while the low risks are unaffected. These results lead us to the conclusion that *both* labor distortions *and* the lack of redistributive power work in the same direction and may even make the corner solution $\alpha = 0$ optimal if precautionary motives are strong.

Finally, we turn to an equilibrium concept that goes back to Wilson (1977) and Miyazaki (1977).[18] It has two interesting properties. First, as shown by Crocker and Snow (1985), it is always second-best efficient. Second, it is a separating equilibrium which still involves cross-subsidization from low to high risks. Its analysis is therefore essentially a careful combination of the results for the Rothschild-Stiglitz separating and the Wilson pooling equilibria. First, it can be shown that the high risks' net social marginal valuation of insurance is zero as in section 4.1 since they obtain full coverage at a marginally fair premium. Second, low risks' utility is not directly affected by a small premium-adjusted increase in insurance coverage. This demonstrates that social insurance can have no positive efficiency impact in case the market equilibrium is second-best. Yet, the distortions resulting from precautionary labor still remain present. Finally, the redistributive impact of social insurance is modified. While it still redistributes from low to high risks as in the Rothschild-Stiglitz case, the effect will be smaller here because low risks already subsidize the high risks in the market. In sum, the fact that no positive efficiency effects but only labor supply distortions arise and the redistributive power is reduced shows that a lower level of social insurance compared to a situation with (first best) efficient private insurance markets will again be optimal if precautionary motives are sufficiently strong.

[17] See, for instance, Cutler and Gruber (1996).

[18] It is often also associated with Spence (1978).

5 Conclusion

We have developed a theory of optimal taxation and social insurance in the presence of imperfect private insurance markets. While the problem of taxation requires to model the households' choice of labor supply endogenously, inefficient insurance markets imply that they have to take this decision under risk. Hence, a theory of labor supply under uncertainty provides the basis for our analysis. As we have shown, there exists a motive for precautionary labor under general and meaningful circumstances.

The integration of imperfect insurance markets into a model of taxation and social insurance allowed us to show how the optimality conditions for public policy based on efficient insurance markets have to be modified. Notably, the strength of the precautionary labor motive turns out to be crucial in determining whether social insurance should be higher or lower compared to earlier results. Social insurance might have efficiency-enhancing effects by reducing underinsurance. At the same time, larger overall insurance coverage leads individuals to reduce their labor supply, which emerges as an important repercussion. Furthermore, social insurance suffers from substantially reduced redistributive power when equilibria with cross-subsidization prevail on markets. Finally, even the positive efficiency effects vanish in a second-best market equilibrium. Using specific equilibrium concepts for the insurance markets, we illustrated these results and showed that it may even be optimal to completely renounce on social insurance as a policy device and only use income taxation to achieve redistributive objectives. This is in stark contrast to conjectures of the previous literature where social insurance provided a means of distortion-free redistribution.

Our paper has raised issues for further research. Our theory of precautionary labor may provide an important and so far unexplored tool for analyzing a variety of other economic problems such as optimal labor contracts, unemployment and macroeconomic fluctuations. In addition, the interaction between precautionary labor and precautionary savings might lead to new and interesting effects in dynamic models that account for the interaction of labor, insurance, and capital markets.

6 Appendix

6.1 Proof of Lemma 2

Consider a damage D that occurs with probability p, and of which a share β is insured. This defines a Bernoulli random variable with expectation $p\,(1-\beta)D$ and variance

$p\,(1-p)[(1-\beta)D]^2$. The first order condition for optimal labor supply $L^*(\beta)$ is

$$w[p\,u'(wL^*+T-(1-\beta)D)+(1-p)\,u'(wL^*+T)]=-v'(L^*). \tag{14}$$

The income effect can be derived by implicitly differentiating (14):

$$\frac{\partial L^*}{\partial T}=-\frac{w\,[pu''(wL^*+T-(1-\beta)D)+(1-p)u''(wL^*+T)]}{SOC}, \tag{15}$$

where SOC stands for the second derivative of the objective with respect to L and is negative. Therefore, the income effect is negative, which implies that leisure is a normal good.

Implicit differentiation of (14) w.r.t. β yields after some rearrangements

$$\frac{\partial L^*}{\partial \beta}=\frac{\partial L^*}{\partial T}pD-\frac{w[u''(wL^*+T-(1-\beta)D)-u''(wL^*+T)]}{SOC}p(1-p)D. \tag{16}$$

The income effect due to decreased expected damage is already visible as the first term on the RHS of (16). Substituting $\Delta u''(\beta)$ for $u''(wL^*+T)-u''(wL^*+T-(1-\beta)D)$, $\mathrm{E}[u''(.)]$ for $p\,u''(wL^*+T-(1-\beta)D)+(1-p)\,u''(wL^*+T)$, together with the income effect (15) and the first derivative of the variance w.r.t to β, the effect (16) can be transformed to

$$\frac{\partial L^*}{\partial \beta}=\frac{\partial L^*}{\partial T}\left[pD-\frac{\partial \Psi}{\partial \beta}\right], \tag{17}$$

where

$$\frac{\partial \Psi}{\partial \beta}=\left(-\frac{\Delta u''(\beta)/(1-\beta)D}{\mathrm{E}[u''(.)]}\right)\left(\frac{1}{2}\frac{\partial \mathrm{Var}}{\partial \beta}\right). \tag{18}$$

6.2 Proof of Proposition 1

Assuming an interior solution, the first order condition for the optimal level of social insurance α given by problem (6) is

$$\sum_{i,j} n_{ij}\frac{\partial V_{ij}^{**}}{\partial \alpha}+\gamma\sum_{i,j} n_{ij}\,\tau w_i\frac{\partial L_{ij}^{**}}{\partial \alpha}=0. \tag{19}$$

The effect of α on L_{ij}^{**} can be reduced to effects on L_{ij}^{*} by explicitly taking into account its effect on the private insurance market equilibrium:

$$\frac{\partial L_{ij}^{**}}{\partial \alpha}=\frac{\partial L_{ij}^{*}}{\partial \alpha}+\left.\frac{\partial L_{ij}^{*}}{\partial \beta_{ij}}\right|_A\frac{\partial \beta_{ij}}{\partial \alpha}. \tag{20}$$

The same decomposition can be applied to V_{ij}^{**}. After some rearrangements, one obtains

$$\sum_{i,j} n_{ij} \left(\frac{1}{\gamma} \frac{\partial V_{ij}^*}{\partial \alpha} + \tau w_i \frac{\partial L_{ij}^*}{\partial \alpha} \right) + \sum_{i,j} n_{ij} g_{ij} \frac{\partial \beta_{ij}}{\partial \alpha} = 0. \tag{21}$$

The first term on the LHS of (21) can further be transformed by noting that effects of α on labor supply can be expressed as effects of β_{ij} as follows:

$$\frac{\partial L_{ij}^*}{\partial \alpha} = \left. \frac{\partial L_{ij}^*}{\partial \beta_{ij}} \right|_A + (d'_{ij} - \bar{p}D) \frac{\partial L_{ij}^*}{\partial T}, \tag{22}$$

where d'_{ij} stands short for $\partial d_{ij}/\partial \beta_{ij}$. Equation (22) follows from the fact the changes in social and private insurance differ only with respect to their different premiums. The same decomposition holds for indirect utility. Substituting this into (21) yields

$$\sum_{i,j} n_{ij} g_{ij} \left(1 + \frac{\partial \beta_{ij}}{\partial \alpha} \right) + \sum_{i,j} n_{ij} b_{ij} (d'_{ij} - \bar{p}D) = 0. \tag{23}$$

After adding and subtracting $\sum_{i,j} n_{ij} \bar{b} (d'_{ij} - \bar{p}D)$ one obtains

$$\sum_{i,j} n_{ij} g_{ij} \left(1 + \frac{\partial \beta_{ij}}{\partial \alpha} \right) + \sum_{i,j} n_{ij} (b_{ij} - \bar{b})(d'_{ij} - \bar{p}D) + \bar{b} \sum_{i,j} n_{ij} (d'_{ij} - \bar{p}D) = 0. \tag{24}$$

The last term on the LHS of (24) is equal to zero since aggregate profits of insurance companies in a competitive market equilibrium are zero. Therefore, higher insurance coverage for all individuals will be accompanied by adjustments in the premiums such that additional revenues equal additional expected insurance payments on the population average.

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