Perceptions et couvertures des risques extrêmes en présence d'incertitudes sur les marchés de l'assurance et de la réassurance

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"Le plus grand dérèglement de l'esprit, c'est de croire les choses parce qu'on veut qu'elles soient, et non parce qu'on a vu qu'elles sont en effet." Bossuet (1670), Traité de la connaissance de Dieu et de soi-même, chapitre 1^{er}, XVI.

"If we pass to the opinion of theorists to the experience of practical men, it might perhaps be held that a presumption in favour of the numerical valuation of all probabilities can be based onto the practice of underwriters and the willingness of Lloyd's to insure against practically any risk. Underwriters are actually willing I might be urged, to name a numerical measure in every case, and to back their opinion with money. But this practice shows no more than that many probabilities are greater or less than numerical definite. It is sufficient for underwriter if the premium he names exceeds the probable risk. But apart from this, I doubt whether in extreme cases the process of thought, through which he goes before naming a premium is wholly rational and determinate or that two equally intelligent brokers acting on the same evidence would always arrive at the same result." Keynes (1921), A treatise on probability, chapter III.

Avertissement

L'introduction générale de cette thèse est rédigée en français et les chapitres suivants en anglais. Mis à part l'introduction, les différents chapitres sont issus d'articles de recherche dont la structure est autonome. Par conséquent, certaines informations, notamment la littérature, sont répétées d'un chapitre à l'autre.

Notice

The general introduction was written in French, and the other chapters in English. Except the introduction, all chapters of this thesis are self-containing research articles. Consequently, some explanations, like corresponding literature, are repeated in different places of the thesis.

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CHAPITRE 1

Introduction Générale

Préambule

À l'échelle mondiale, ces vingt dernières années, le bilan humain et économique des catastrophes naturelles et industrielles a augmenté. L'année 2011 a connu les plus importants dommages économiques liés à des risques extrêmes jamais enregistrés, avec plus de 403 milliards de dollars. Le séisme au Japon et les incidents nucléaires qui en ont résulté, mais aussi les séismes en Nouvelle-Zélande, en Turquie, les inondations en Australie et en Thaïlande, ont été d'une ampleur inégalée. Or, seulement 126 milliards de dollars ont été pris en charge par les assureurs et réassureurs. L'année 2012 s'est également avérée importante de ce point de vue, avec 186 milliards de dollars de dommages économiques, dont 77 réassurés et plus de 14 000 victimes [1]. Les dommages non assurés sont difficilement absorbés par la société. Les marchés de l'assurance et de la réassurance sont essentiels pour accroître la résilience de la société face à de tels risques : ainsi est-il nécessaire d'identifier et d'évaluer correctement les événements extrêmes et les décisions conséquentes, afin d'optimiser la prise en charge de ces risques.

Évaluer correctement les caractéristiques des événements - c'est-à-dire les pertes potentielles et la probabilité d'occurrence associée - est crucial pour l'assurabilité d'un risque, car cela permet l'utilisation de méthodes actuarielles afin de calculer le prix des contrats d'assurance. Toutefois, certains risques ne vérifient pas nécessairement cette condition. C'est le cas des catastrophes naturelles, de la pollution environnementale ou des risques associés aux nouvelles technologies, en raison de l'indisponibilité de données historiques, du changement climatique ou de nouvelles réglementations. Pour ce qui est de la demande d'assurance, les individus ne sont pas forcément en mesure d'évaluer leurs risques ; et relativement à l'offre, les professionnels de l'assurance utilisent des outils de modélisation qui peuvent produire des estimations imprécises ou controversées. Lorsque l'information sur les risques est ambiguë, les techniques actuarielles classiques ne peuvent pas être utilisées car les hypothèses de base ne sont plus vérifiées, ce qui occasionne des problèmes pour la tarifi-

1. Sigma 2 (2013) et Munich Re (2013).

cation des contrats d'assurance. De même, les modèles classiques de demande d'assurance ne sont pas directement transposables aux risques dont les caractéristiques se révèlent mal connues. Ces caractéristiques des risques, la précision de l'information disponible et les facteurs psychologiques des agents (attitude vis-à-vis du risque et des pertes, expérience passée, préférences et personnalité), sont des facteurs déterminants pour la compréhension des choix au sein des marchés de l'assurance.

Parmi la littérature sur la prise de décision, Keynes (1921) et Knight (1921) distinguent pour la première fois le risque, situation dans laquelle les probabilités sont connues et unanimes, et l'incertitude, situation où elles ne le sont pas. Le terme "ambiguïté" a été introduit par Ellsberg (1961) lors de sa critique normative du modèle d'espérance d'utilité subjective de Savage (1952). Depuis lors, l'ambiguïté fait référence à un type particulier d'incertitude, désignant des cas où les décideurs ne connaissent pas précisément la probabilité d'occurrence d'un événement. Ces situations d'ambiguïté sont très fréquentes dans la vie quotidienne, et il est assez rare pour les décideurs de connaître réellement la probabilité exacte des événements futurs (comme c'est le cas notamment pour les jeux de hasard). La connaissance des probabilités est le plus souvent partielle, en raison d'un manque d'expérience, d'informations contradictoires ou de données peu crédibles : les décisions sont donc plus délicates à prendre.

Certaines controverses scientifiques récentes illustrent parfaitement les effets liés à l'ambiguïté. En particulier, les incertitudes autour du changement climatique donnent lieu à de nombreux débats, entraînant ainsi d'autres incertitudes quant à la prévision de catastrophes naturelles, en termes d'intensité et de fréquence. Personne ne connaît les effets du changement climatique, à quel point ils vont être rapides, progressifs et inscrits dans la durée. Par ailleurs, tant que l'historique n'est pas significatif, les assureurs sont dans l'incapacité de prévoir la distribution des pertes et des fréquences. En conséquence, cela conduit à des difficultés dans la tarification des instruments de couverture des risques liés aux catastrophes naturelles.

Ces incertitudes remettent en question le cadre conventionnel d'analyse qu'est le modèle d'espérance d'utilité développé par von Neumann et Morgenstern (1947), et que Savage (1954) a étendu à l'incertitude en remplaçant la distribution objective par une distribution de probabilité subjective, lorsque les probabilités ne sont pas objectives. Or ce modèle ne prévoit pas que l'individu puisse douter de ses croyances sur les probabilités en présence d'information partielle, ou de la probabilité qui lui est donnée. Il n'est pas toujours possible de définir des probabilités précises pour les événements futurs. Ce modèle a donc été critiqué et jugé insuffisant dès les années 1950 (Allais, 1953 ; Ellsberg, 1961), mais ce n'est que plus tard que les économistes ont développé de nouveaux modèles, prenant en compte les décisions en situation d'incertitude et expliquant l'aversion à l'ambiguïté (Schmeidler, 1989 ; Gilboa et Schmeidler, 1989 ; Ghirardato et al, 2004 ; Klibanoff et al, 2005 ; Gajdos et al, 2008). D'un point de vue empirique, les travaux analysant les comportements en présence d'ambiguïté sont très nombreux ; ce qui illustre l'importance de ce sujet dans la littérature sur la prise de décision (Camerer et Weber, 1992).

En parallèle, la psychologie fait la distinction entre deux types d'ambiguïté : l'imprécision, situation dans laquelle l'information est consensuelle mais imprécise, et le conflit, situation où il y a désaccord entre experts. Smithson (1999) définit l'aversion au conflit comme le fait que les individus préfèrent une information consensuelle à une situation controversée. Il explique que les conflits sont perçus comme moins crédibles, les experts apparaissant moins dignes de confiance lorsqu'ils ne sont pas d'accord, du fait peut-être d'un manque de communication et de partage d'information entre eux. Cabantous a appliqué cette théorie à des individus spécialement confrontés aux problématiques pointues et complexes de gestion de risques : les assureurs (Cabantous, 2007 ; Cabantous et al, 2011). Le résultat est que les assureurs sont également adversaires au conflit, et qu'il est intéressant de comprendre comment cette population particulière gère les risques en présence d'imprécision et de conflit.

Le cadre de l'assurance

De nombreuses activités économiques n'auraient pas lieu sans assurance, du fait des risques associés. Les créations d'emplois et la croissance ralentiraient, de même l'innovation, qui est risquée par définition, serait fortement découragée. Henri Ford (1863-1947), parlant de New York au début du 20ème siècle, a dit :

> *"Cela n'a été rendu possible que par les assureurs. Ce sont eux qui ont vraiment bâti cette ville. En l'absence d'assurance, il n'y aurait pas de gratte-ciel. Aucun investisseur ne financerait des bâtiments qu'un seul mégot de cigarette pourrait faire brûler entièrement."*

Le secteur de l'assurance et de la réassurance est un important investisseur institutionnel. En 2009, le secteur a géré près de 23 trillions de dollars d'actifs, soit environ 13% du total des actifs financiers dans le monde [2]. Les (ré)assureurs sont des investisseurs prudents, orientés vers le long terme, et contribuant ainsi à soutenir l'économie réelle. L'industrie de l'assurance permet donc aux économies de s'adapter et d'accroître leurs résistances aux événements adverses. De ce fait, elle possède une expertise concernant l'identification et l'estimation des risques, la mitigation et l'adaptation face aux risques, et le transfert de ces risques.

Dans une compagnie d'assurance, des situations ambiguës peuvent se présenter sous plusieurs formes. Comprendre l'incertitude incluse dans l'estimation des risques extrêmes et dans le processus de prise de décision devient alors un enjeu opérationnel et stratégique pour un assureur, ce qui lui permet en outre de déterminer les primes d'assurance et de réassurance de la manière la plus performante. La compagnie d'assurance peut ainsi améliorer la modélisation, la perception et la gestion des risques pour optimiser les stratégies de gestion des risques extrêmes (souscription, réassurance, Cat bonds, etc.).

Ce travail de recherche, réalisé en partenariat avec le Groupe AXA, a permis de mettre en relation des problématiques économiques de la prise de décision en ambiguïté avec celles

2. Swiss Re

d'une grande compagnie d'assurance acteur majeur sur le marché et faisant face à une multitude de risques et d'incertitudes. En plus de concrétiser le sujet de thèse, le partenariat a également étoffé le travail grâce au partage d'informations et de connaissances. En effet, la thèse s'est trouvée fortement enrichie par l'accès à des données d'assurance jamais analysées d'un point de vue académique. De surcroît, côtoyer des professionnels spécifiquement experts dans ces domaines, offre la possibilité d'analyser leurs décisions et comportements "au coeur du sujet". Enfin, la découverte et l'encadrement des pratiques de l'entreprise ont apporté une vision empirique. Dans le département de gestion des risques, j'ai fait partie intégrante de l'équipe analysant les risques de catastrophes naturelles. Ainsi ai-je participé au travail opérationnel : par l'analyse de Cat bonds émis sur le marché de la titrisation des risques catastrophiques, mais aussi à travers l'étude des risques couverts par des entités du Groupe, afin de déterminer une recommandation de réassurance permettant une protection contre des événements de faible probabilité. En contrepartie, pour l'entreprise, le travail de thèse a favorisé une étendue des connaissances, de la compréhension des risques et des incertitudes auxquels elle fait face. Elle a pu considérer sous un autre angle certains biais de perception des assureurs dans le but d'améliorer leurs décisions, spécialement celles d'agrégation de l'information ambiguë et l'analyse de l'offre de réassurance.

Pour une compagnie d'assurance, il existe des risques "normaux", et d'autres, plus ambigus. Les risques "normaux", appelés "attritionnels", sont de faibles coûts, nombreux, répétitifs et indépendants, que l'on peut analyser à partir de données historiques et de distributions de probabilités précises. Ces risques sont facilement mutualisables. Certains risques sont ambigus dans le sens où leurs distributions de probabilités ne peuvent pas être estimées précisément (ni leurs conséquences possibles, mais nous supposons ici qu'elles ne sont pas ambiguës). Les données historiques ne sont pas forcément disponibles (pour les risques nouveaux, dits "émergents", et spéciaux, dits "atypiques"), ou pas en quantité suffisante (pour les risques extrêmes, comme les catastrophes naturelles). Les professionnels de l'assurance compensent ces obstacles en utilisant plusieurs outils de modélisation afin de quantifier ces risques. Ces outils, que l'on peut qualifier d'"experts", sont des représentations de la réalité pouvant produire des estimations imprécises ou contradictoires.

Les risques considérés comme "imprécis" sont notamment les risques naturels (tempête, ouragan, grêle, tremblement de terre), pour lesquels l'estimation se fait à partir de logiciels utilisant des modèles stochastiques. Concernant les risques naturels, ces logiciels utilisent, entre autres, des modèles de météorologie et de sismologie ainsi que des hypothèses de construction des bâtiments, de mitigation des risques, et de concentration des capitaux. Ils estiment le risque à partir de ce qu'ils appellent l'aléa, i.e. la fréquence et l'intensité de l'évènement, l'exposition, i.e. les enjeux et valeurs socio-économiques, et la vulnérabilité, i.e. le degré auquel ces valeurs seront effectivement détruites [3]. Les assureurs utilisent ces modèles avec plusieurs hypothèses possibles, selon ce qu'ils anticipent de l'exposition et de la vulnérabilité de leur portefeuille : ceci entraîne une information imprécise, la distribution de probabilité (ou celle de pertes) recherchée se trouvant dans un intervalle.

En outre, les assureurs utilisent généralement plusieurs modèles, ce qui conduit souvent à des conflits d'estimations. Il existe trois modèles disponibles sur le marché pour l'évaluation des risques naturels : les modèles de AIR Worldwide, EqeCat, et Risk Management Solutions (RMS). Ils sont apparus dans les années 1980, mais leur utilisation a été exponentielle à partir de 1992, avec l'ouragan Andrew. Ces outils donnent des estimations dissemblables car ils sont basés sur des modélisations et hypothèses différentes, mais on ne peut pas désigner une méthode meilleure qu'une autre. Les assureurs doivent donc agréger les informations de ces modèles afin d'estimer leurs risques, influencés par leurs attitudes face au risque et à l'ambiguïté ; il en résulte une perte d'information et un ajout possible d'incertitudes [4]. De plus, pour les risques "atypiques" (par exemple l'assurance d'une usine), les assureurs tarifient les contrats en utilisant des scénarios plus ou moins extrêmes. Ces modèles et situations comprennent ainsi un fort niveau d'ambiguïté. En

3. Les hypothèses d'exposition dépendent du degré de dangerosité et sont liées à l'environnement, notamment aux caractéristiques du sol, à la position par rapport au vent, aux zones potentiellement inondables, etc. Les hypothèses de vulnérabilité se rapportent aux matériaux de construction des bâtiments (le béton armé étant plus solide que le bois), et proposent, par exemple, une distribution des différents types de construction par zone analysée. Ensuite, un module financier combine ces hypothèses avec des estimations sur la fréquence et l'intensité des événements naturels (à partir de données météorologiques), afin d'estimer les pertes possibles. Le risque est donc défini de la façon suivante : $Risque = al\acute{e}a \times pertes = al\acute{e}a \times (exposition \times vuln\acute{e}rabilit\acute{e})$ (Rapport CAE, 2012).

4. L'agrégation se fait avec des facteurs (par exemple, $x_1 * RMS + x_2 * AIR + x_3 * EQE$ avec $x_1 + x_2 + x_3 = 1$, les poids de chaque modèle) choisis à partir d'une évaluation des modèles réalisés en interne par les assureurs.

conséquence, les professionnels de l'assurance se doivent d'être particulièrement conscients que les jugements humains et les biais de perception font partie du processus d'estimation des événements extrêmes.

La gestion des risques est au coeur du métier de l'assurance, et l'évaluation des risques est utilisée pour le calcul de la prime, la couverture de réassurance, et l'estimation du capital économique de l'entreprise. Une évaluation correcte des risques permet à l'assureur de couvrir au mieux les assurés, tout en réduisant son propre risque de défaut. Cela s'avère d'autant plus important que les décisions doivent être en conformité avec la nouvelle réglementation européenne. La directive Solvabilité II devrait aboutir à une meilleure compréhension des risques réels des compagnies d'assurance, à générer une gestion plus pointue de ces risques ainsi qu'une plus grande transparence de leur assurance. En effet, elle instaure une meilleure visibilité dans l'estimation par une exigence accrue de documentation et de justifications. Elle oblige les assureurs à analyser rigoureusement leurs risques afin de déterminer un niveau de capital suffisant à détenir. De nombreux assureurs ont déjà commencé à optimiser leurs activités, ce qui, à l'aune de cette nouvelle réglementation, apparaît clairement comme un début. Des changements significatifs dans l'orientation de leurs activités devraient en résulter. Auparavant, Solvabilité I se concentrait sur une estimation rétrospective du capital à partir de l'historique des pertes et des primes, analyse imparfaite qui ne prenait pas en compte les risques du portefeuille actuel.

La directive Solvabilité II modifie donc les comportements de gestion des risques, vers une analyse qu'on pourrait qualifier de "scientifique". Elle accroît la nécessité, pour les assureurs, de mieux comprendre leurs risques et de collecter davantage d'informations, dans le but d'accéder à une vision plus exhaustive. Bien sûr, le problème demeure : personne ne connaît la "vraie" probabilité ni le "meilleur" modèle. Collecter plus d'informations peut toutefois permettre d'identifier des situations ambigües auxquelles il est difficile de faire face, et il est probable que les réassureurs soient mieux à même de gérer ces situations d'ambiguïté. Les réassureurs ont l'avantage d'être des acteurs plus globaux, nantis d'une plus large expertise. Ils appliquent directement la loi des grands nombres, du fait d'une mutualisation géographique des risques leur permettant une moindre corrélation entre eux (les assureurs étant limités géographiquement, les risques liés à un événement naturel se trouvent corrélés). La réassurance est un outil important de gestion des risques et de financement de l'économie, et ses effets économiques auront un impact plus immédiat sur l'exigence de capital dans le nouveau régime.

Ce travail de thèse a pour finalité de répondre à des problématiques globales liées à la communication et à la réglementation des risques extrêmes dans le secteur de l'assurance. Dans ce sens, la nouvelle réglementation apporte un contexte général très intéressant, par l'obligation d'analyser correctement les risques et le caractère micro-économique de l'implémentation de la Directive. Le rôle et le fonctionnement de l'assurance peuvent être approfondis en tenant compte de l'impact des risques extrêmes, des décisions et de leurs déterminants. Par ailleurs, la compréhension de ces comportements améliore la communication autour des risques extrêmes, ce qui a des conséquences sur l'augmentation de la couverture d'assurance globale, et donc sur la résilience de la société.

La recherche présentée dans cette thèse appartient à la littérature empirique sur les décisions économiques en ambiguïté. Son objectif est d'améliorer la compréhension des décisions de couverture des risques sur les marchés de l'assurance et de la réassurance, selon l'information disponible. Cette thèse se concentre sur l'analyse des effets de l'ambiguïté sur les décisions d'assurance, en particulier sur les primes que les agents sont prêts à payer ou accepter pour transférer (ou supporter) des risques spécifiques. Elle s'attache également aux facteurs explicatifs des primes d'assurance et de réassurance qui ne sont pas uniquement définies par les caractéristiques des risques. À travers l'étude des comportements des assurés, assureurs et réassureurs, est-il possible de mettre en évidence des comportements différents selon le type d'information ? Comment se distinguent les décisions répondant à des risques ambigus de celles répondant à des risques bien connus ? Les agents de ces marchés sont-ils systématiquement adversaires à l'ambiguïté ? Que décident-ils selon que l'information est imprécise ou contradictoire ? Comment définissent-ils leurs prix de réserve en présence d'information incomplète ? En quoi les comportements d'offre et de demande peuvent-ils se concilier ? Enfin, comment ces primes d'assurance et de réassurance sont-elles déterminées, et par quoi sont-elles influencées ?

Structure de la thèse

La thèse est constituée de deux parties distinctes et de cinq chapitres, utilisant une large palette d'outils quantitatifs. Chaque chapitre est une contribution de nature empirique sur les décisions de couverture des risques, et contient un point de vue différent et complémentaire sur les décisions d'assurance.

La première partie porte sur les comportements d'assurance en présence de risque, d'imprécision et de conflit. Le chapitre 2 consiste en une enquête sur la demande d'assurance, distribuée à un échantillon représentatif de la population française. Cet article a été publié dans *Insurance and Risk Management*, volume 80 (2) en 2012. Le chapitre 3 analyse, à partir de l'enquête élargie du chapitre précédent, les comportements d'assurance des professionnels de l'assurance, aussi bien du côté de l'offre que de la demande. Il met aussi en relation les comportements du grand public et des assureurs. Le chapitre 4 apporte une vision expérimentale de ces comportements d'assurance, complémentaire aux précédentes.

La seconde partie étudie le marché de la réassurance. Le chapitre 5 résume la littérature et les principales spécificités de ce marché. Le chapitre 6 analyse les caractéristiques de l'offre des réassureurs, à partir d'une base de données de prix de réassurance.

Partie I - Les comportements d'assurance face à de l'information ambiguë

Chapitre 2 - La demande d'assurance en présence d'ambiguïté et de conflit pour les risques extrêmes : Résultats d'une vaste enquête représentative

Ce chapitre de la thèse analyse les comportements d'assurance du grand public face au risque, à l'ambiguïté et au conflit, concernant les risques extrêmes. Au moyen d'un questionnaire distribué à un large échantillon représentatif de la population française, l'objectif est de déterminer la demande d'assurance pour des risques extrêmes et ambigus, par des sujets a priori non avertis et non familiers des probabilités. Les résultats de ce chapitre montrent que la décision d'assurance peut se diviser en deux catégories distinctes et successives : la décision d'acheter de l'assurance, et la décision du consentement maximal à payer. Dans la première décision, plus de 25% des sujets refusent de s'assurer, et sont plus enclins à s'asssurer en présence de risque que d'ambiguïté. Le refus d'assurance s'explique en partie par les caractéristiques des individus : en réalité, refuser de s'assurer ne révèle pas d'aversion au risque décrit, mais une aversion au risque de non remboursement de la part de l'assureur. Ce résultat dénote un manque de confiance dans le marché de l'assurance. Les individus font preuve de défiance vis-à-vis de l'industrie de l'assurance, et partent du principe que les assureurs ne vont pas les rembourser, ou pas correctement, en cas d'événements adverses.

Pour ce qui est de la seconde décision, les individus ne montrent pas d'aversion à l'ambiguïté, comme on pourrait s'y attendre. Ils considèrent les situations ambiguës (incluant l'imprécision et le conflit) comme inférieures (Weber, 1993), et sont réticents à payer parce qu'ils se sentent mal à l'aise dans ces situations. En outre, les personnes se comportent différemment dans l'imprécision et dans le conflit. Elles préfèrent la situation où l'information est consensuelle et cherchent à éviter les conflits. Cependant, les consentements à payer ne sont pas corrélés de la même façon avec les caractéristiques observables que dans la première décision.

Ainsi, du côté de la demande, les gens présentent de l'aversion au risque, mais la prime qu'ils sont prêts à payer diminue en présence d'ambiguïté. Du côté de l'offre, de précédentes études ont montré que les assureurs ne sont que légèrement adversaires au risque, mais le sont fortement à l'ambiguïté (Cabantous, 2007 ; Cabantous et al, 2011). Sur un marché concurrentiel, l'offre doit répondre à la demande. Par conséquent, un marché peut exister en présence de risque, mais plus difficilement en présence d'ambiguïté. Afin qu'existe un marché d'assurance efficient pour les risques extrêmes ambigus, il est important que les assurés et les assureurs aient la vision la plus proche possible des caractéristiques des risques.

Chapitre 3 - Les professionnels de l'assurance face à l'imprécision et au conflit pour les risques extrêmes : Comment l'information affecte-t-elle la prime d'assurance ?

Le troisième chapitre de la thèse complète le premier, puisqu'il analyse les comportements des professionnels de l'assurance à partir d'une enquête similaire à celle du chapitre précédent. Il n'existait pas d'analyse comparable de l'offre et de la demande d'assurance en présence d'imprécision et de conflit. Il est possible que les professionnels de l'assurance soient plus fréquemment confrontés à la présence d'ambiguïté, du fait de leur coeur de métier et des différents experts, ou logiciels, qu'ils utilisent pour la modélisation des catastrophes naturelles.

Nos résultats fournissent la preuve que les professionnels de l'assurance représentent une population spécialisée, se comportant différemment du grand public, et raisonnant en termes actuariels même en tant que simples assurés. Cependant, ils ont aussi des difficultés à évaluer des situations ambiguës. Les professionnels de l'assurance présentent de l'aversion au risque, à l'ambiguïté, et au conflit. Ils sont plus enclins à acheter et vendre de l'assurance dans le risque que dans l'ambiguïté. Ces refus d'assurance sont liés à un déni des événements extrêmes du côté de la demande, et à des comportements de marché du côté de l'offre - les professionnels sachant qu'une prime trop élevée ne sera pas acceptée. Les assureurs ne raisonnent pas entièrement à partir de leurs attitudes face aux risques, mais aussi par rapport à des stratégies de marché.

De plus, les prix demandés par les professionnels de l'assurance sont inférieurs à ceux qu'ils sont prêts à offrir. En revanche, sur le marché de la réassurance, les prix demandés sont supérieurs aux prix offerts, car l'assureur reconnaît que le réassureur a une meilleure expertise des risques extrêmes. Les agents semblent plus adversaires à l'ambiguïté sur le marché de l'assurance, et davantage adversaires au risque sur le marché de la réassurance. D'autre part, plus l'ambiguïté est forte, plus la prime est élevée, et plus la justification des choix est difficile. Ce chapitre montre que les processus de décision sont différents dans le risque et dans l'ambiguïté, du côté de la demande comme de l'offre.

Ce chapitre fait également le lien avec la demande d'assurance du grand public examinée au chapitre précédent. Il montre que les professionnels de l'assurance ne se comportent pas comme des assurés ordinaires, l'écart entre les prix demandés du grand public et les prix offerts par les assureurs étant encore plus grand. Également, en comparant les décisions des professionnels de l'assurance avec un sous-ensemble "qualifié" de l'échantillon du grand public, les primes d'assurance diffèrent, ainsi que les facteurs explicatifs. Les décisions d'assurance dépendent des caractéristiques objectives des risques (telles que le type du risque, l'information et la probabilité de perte) et des préférences individuelles, elles-mêmes influencées par les caractéristiques démographiques (telles que l'âge, le genre, le statut matrimonial, le nombre d'enfants, et l'expérience passée). Néanmoins, la perception subjective du risque (ici, la perception du risque de terrorisme), qui est un facteur significatif pour les individus dits "normaux", n'est pas significatif pour les professionnels de l'assurance, puisque ceux-ci doivent surtout se focaliser sur des données objectives. De surcroît, les effets liés à l'âge et au type d'expérience diffèrent également.

Chapitre 4 - Les comportements d'assurance face à différents types d'information : Une étude expérimentale

Ce chapitre apporte une approche complémentaire aux deux précédents. Il s'agit d'une étude d'économie expérimentale, utilisée pour la première fois pour analyser les comportements face à une information conflictuelle. Dans ce chapitre, les sujets révèlent leurs préférences pour des risques de faible probabilité et fortes conséquences, et des risques de forte probabilité et faibles conséquences, face à quatre types d'information concernant la probabilité d'occurrence. La probabilité est estimée par deux experts. Dans le risque (R), les experts s'accordent à dire que la probabilité est bien connue et précise. Dans l'imprécision (I), ils sont d'accord sur un intervalle de valeurs possibles, mais ne peuvent pas affiner l'estimation. Dans le conflit (C), ils sont en désaccord et chacun a sa propre estimation. Enfin, dans le conflit imprécis (IC), ils sont en désaccord et chacun a sa propre estimation imprécise de la probabilité. Les sujets jouent deux sessions expérimentales relatives des deux côtés du marché. Du côté de la demande, ils choisissent leur couverture contre des pertes possibles ; du côté de l'offre, ils acceptent ou non de souscrire des contrats d'assurance à des clients. Des mécanismes de BDM (Becker-DeGroot-Marschak) sont utilisés pour obtenir le consentement à payer (WTP) et à accepter (WTA), les quantités achetées et vendues, et les probabilités subjectives. Contrairement aux expériences d'assurance classiques, les choix ne sont pas hypothétiques, les sujets sont rémunérés en fonction de leur performance.

On observe quatre principaux résultats. Premièrement, l'étude fait ressortir un classement de primes d'assurance en fonction du type d'information ($\pi_R < \pi_I \leqslant \pi_C < \pi_{IC}$), qui est plus significatif pour les acheteurs que pour les vendeurs d'assurance. Deuxièmement, les résultats montrent également que les événements extrêmes sont davantage sous-estimés que les événements plus probables, et que les individus sont plus disposés à acheter ou souscrire une assurance pour les événements plus probables. Troisièmement, les WTP sont inférieurs au WTA, et l'écart entre ces deux primes est plus élevé pour les événements extrêmes. De plus, cet écart diminue avec l'ambiguïté. Concernant les quantités, il y a plus d'achats et moins de ventes en présence d'ambiguïté, entraînant une hausse du prix mais une quantité échangée relativement stable. De plus, les échanges possibles sont plus importants pour les événements probables que pour les événements extrêmes.

Quatrièmement, des effets de cadrage jouent un rôle important dans les comportements selon le type d'événement, le contexte et la forme des questions. Les résultats sont plus élevés dans un contexte d'assurance que de loteries quand on raisonne en termes de prix, mais pas en termes de probabilités. Également, l'écart entre les questions sur les prix et celles sur les probabilités augmente avec la difficulté et l'ambiguïté des situations. Enfin, les décisions d'assurance sont fortement influencées par les caractéristiques objectives des risques, les attitudes face au risque et aux pertes, les traits de personnalité et l'expérience passée.

Partie II - Analyses du marché de la réassurance

Chapitre 5 - Le marché de la réassurance : Description et structure

Le cinquième chapitre propose une démarche différente des précédentes, puisqu'il présente le marché de la réassurance à travers un descriptif général du rôle et du fonctionnement de ce marché. Il rappelle la littérature empirique existante, documente le vocabulaire particulier utilisé et les spécificités de ce marché, et s'appuie sur des statistiques agrégées afin d'améliorer notre compréhension de l'importance économique de la réassurance. Par le transfert, la diversification et le regroupement des risques, le marché de la réassurance combine à la fois des décisions de gestion des risques, de partage des risques, et de structure financière. Bien que considéré comme "opaque", ce marché joue un rôle crucial en aidant les économies à s'adapter et à devenir plus résistantes face à des événements adverses.

Chapitre 6 - Les comportements d'offre sur le marché de la réassurance

Le dernier chapitre de la thèse fournit une analyse de l'offre de réassurance et des comportements des réassureurs, en prenant comme bases les notions introduites au chapitre 5. Ce chapitre présente la structure des contrats de réassurance par l'utilisation d'une base de données exclusive sur les échanges entre assureurs et réassureurs. Ces données comportent l'ensemble des cotations (i.e. des devis) demandées par toutes les filiales d'une grande compagnie d'assurance à des réassureurs entre 2005 et 2010, pour toutes les tranches de traités du type "excédent de sinistres" (ou "excess of loss") et pour tous les risques que les filiales ont souhaité réassurer. L'avantage de cette base de données est qu'il n'y a aucun biais d'échantillonnage, car elle comprend tous les échanges (ou absence d'échange) entre des assureurs et des réassureurs. Un certain nombre de facteurs expliquent les cotations sur le marché de la réassurance. Des modèles de régression montrent que l'offre des réassureurs est fortement expliquée, entre autres, par la limite de la tranche (+), sa priorité (-), et sa hauteur (-). Ces déterminants tiennent compte de la tranche, du traité et du marché. La composition du traité apparaît donc comme un signal pour les réassureurs sur les risques de la cédante. À partir de ces éléments, trois résultats principaux sont mis en évidence.

Le premier résultat révèle que le type de risque (i.e. la branche d'assurance) est une caractéristique essentielle de l'offre de réassurance. Les structures des traités et les cotations des tranches diffèrent selon les branches d'assurance, du fait de leurs besoins en capitaux et en expertise, ce qui est lié à l'ambiguïté plus ou moins grande entourant ces risques. L'assureur doit donc faire un arbitrage entre le montant de la cotation, la solidité financière et l'expertise du réassureur.

Le deuxième résultat est relatif aux comportements individuels des réassureurs, lesquels varient selon la tranche, le traité, la branche d'assurance, et dans le temps, en fonction de la taille, du capital et de l'expertise des réassureurs. En particulier, les stratégies d'offre des réassureurs peuvent suivre une approche de diversification (i.e. proposer des cotations sur de nombreux risques et de nombreuses tranches), ou bien une approche de niche (i.e. se spécialiser sur un certain type de risque ou de tranche). Tout d'abord, plus la tranche reçoit de cotations de réassureurs, plus la cotation est faible, démontrant ainsi que le marché de la réassurance est assez concurrentiel bien qu'oligopolistique et de gré à gré. Ensuite, on trouve différentes stratégies selon l'importance du réassureur. Globalement, plus le réassureur possède de parts de marché, plus la cotation est faible. Les plus gros réassureurs recherchent une relation à long terme avec les cédantes et proposent des cotations faibles, du fait de leur expertise élevée. Ils ont une meilleure possibilité de diversification et proposent, en général, des cotations sur l'ensemble des tranches du traité afin d'optimiser leur processus d'évaluation. Toutefois leur suprématie s'est ternie avec l'apparition de nouveaux participants, capables de devenir apériteur (ou "leader"). Les réassureurs de taille moyenne offrent des cotations compétitives sur les traités à une tranche, et sont devenus des acteurs importants depuis 2008. Ces réassureurs ont suivi un processus de tarification selon le concours de beauté de Keynes, afin de se maintenir sur le marché et d'acquérir une expertise. Enfin, les petits réassureurs sont extrêmement hétérogènes, munis d'une expertise éventuellement très spécialisée mais non globale. Ils sont en processus d'apprentissage et leurs cotations sont fortement volatiles. Malgré un risque élevé de défaut, ils peuvent être utilisés ponctuellement, en particulier pour les branches courtes d'assurance.

Le dernier résultat découle des précédents et souligne que le marché de la réassurance a évolué au cours du temps : cela implique une complexité croissante de la composition des traités par des phénomènes de découpage et de regroupement de tranches, et une augmentation du nombre d'acteurs - ce qui a modifié le métier de réassureur.

Conclusions et perspectives

Les enseignements généraux de cette thèse sont de plusieurs ordres. La première perspective est relative aux questions de traçabilité des risques lors des transferts entre assurés, assureurs et réassureurs, avec la possibilité d'un risque systémique en cas d'événement grave incorrectement couvert. Les difficultés de couvertures liées à la sous-assurance (demande et/ou offre insuffisantes) et à la mauvaise estimation des risques (en cas de risques ambigus) soulèvent des questions de réglementation.

S'agissant de la nouvelle directive européenne, Solvabilité II propose aux assureurs une formule standard déterminant le niveau minimum de capital à détenir ; néanmoins les assureurs peuvent aussi créer leur propre modèle interne, sous réserve qu'il soit validé par les régulateurs. Beaucoup choisissent cette deuxième possibilité afin d'avoir une estimation plus fine et plus complète de leurs risques, et donc du niveau de capital à détenir. Mais alors, cette situation soulève la question suivante : les régulateurs ont-ils vraiment l'expertise et les moyens de tout vérifier ? D'autant plus que la directive est différente pour les compagnies de réassurance. De plus, de nombreuses compagnies d'assurance européennes se réassurent chez des réassureurs non européens ayant un cadre législatif faible ou inexistant. Les assureurs utilisent la réassurance afin d'accroître leur capacité de souscription sous Solvabilité II, et de bénéficier de l'expertise des réassureurs. Or, il est essentiel pour les assureurs d'estimer le risque de contrepartie des réassureurs, i.e. leur risque de défaut, ce qui n'est pas aisé. De plus, l'expertise des réassureurs est fondée sur une information tronquée : ils analysent uniquement les pertes élevées et n'ont pas accès aux pertes de faible ampleur. Ils font également face à des problèmes d'aléa moral et de sélection adverse de la part des assureurs.

À propos de la réglementation française des catastrophes naturelles, certains risques (hors tempête, un des principaux risques en France métropolitaine) sont automatiquement pris en compte dans les contrats d'assurance à hauteur d'un taux uniforme sur tout le territoire, principe fondé sur la solidarité nationale. La Caisse Centrale de Réassurance (CCR) propose aux assureurs des tarifs avantageux. Cependant le critère d'assurabilité des risques n'est pas clairement explicité, l'équilibre financier de la CCR serait remis en cause en cas d'événement très grave, et le système n'encourage pas les mesures de prévention (Rapport CAE, 2012). De multiples avancées peuvent donc encore être mises en place.

Un autre enseignement de cette thèse est relatif à la perception des risques extrêmes et ambigus par les acteurs du marché, perception qui influence les comportements. Les biais comportementaux entrainent les assurés, assureurs, réassureurs et même les régulateurs, à prendre des décisions d'assurance non efficientes pour les événements de faible probabilité. Les assurés se concentrent trop sur leur expérience récente et leur perception subjective des risques ; les assureurs ne calculent pas correctement les risques et leurs corrélations ; les réglementations sont influencées par les marchés financiers et l'agenda politique. Afin de résoudre ces problèmes, l'assurance des risques extrêmes doit être plus transparente et proche des risques individuels. Les assureurs pourraient notamment développer des méthodes d'estimation de risques en s'appuyant sur des données accessibles à chacun, collectives et objectives, tout en ayant connaissance des possibles erreurs de jugement.

La dernière perspective porte sur la communication autour des risques. Il faut fournir aux assurés des informations sur le rôle de l'assurance et l'importance de ce marché dans l'activité économique. Les individus doivent savoir que le meilleur retour sur investissement d'un contrat d'assurance survient lorsqu'il n'y a pas d'occurrence de risque. Il est important de faire comprendre aux agents que les risques extrêmes peuvent avoir des conséquences dévastatrices qu'il est possible d'éviter. La communication doit passer par les compagnies d'assurance, qui ne doivent pas forcément s'exprimer de la même manière en fonction des risques et de l'information disponible. Les assureurs ont la responsabilité de dispenser des informations qualitatives et quantitatives, afin d'éviter des jugements hâtifs, voire erronés, sur certains risques. Il faut également présenter les risques comme étant une préoccupation personnelle des assurés. Les individus doivent se sentir concernés, parce qu'ils ne gèrent pas de la même manière les événements naturels et ceux causés par l'homme. Ils pensent pouvoir contrôler leur propre attitude face au risque. Le rapport OECD de 2011 documente des mesures prises par des assureurs et le service public, au moyen de campagnes de publicité et de groupes de travail, afin d'informer et d'éduquer le grand public sur les risques. Le secteur de l'assurance tirerait un grand profit en améliorant sa réputation et en accroissant la confiance des assurés. Les assureurs ont donc tout intérêt à davantage de transparence dans leurs prix, les produits devant être présentés de façon réaliste afin de diminuer les asymétries d'information entre les deux parties. Il est capital de reconnaître que des incertitudes existent autour de certains risques. En outre, la réputation des compagnies d'assurance semble s'améliorer une fois que les gens ont effectivement déclaré un dommage. Il apparaît donc essentiel de développer le nombre de clients et de les fidéliser, en se montrant présent et réactif lors de dommages. Ces recommandations conduisent à améliorer la réputation et donc le fonctionnement du secteur de l'assurance, secteur qui doit aussi jouer un rôle décisif dans la prévention et la mitigation des risques.

PART I

Insurance Behaviors facing Ambiguous Information

CHAPTER 2

Insurance demand under ambiguity and conflict for extreme risks: Evidence from a large representative survey

2.1 Introduction

The assessment of the risk characteristics, i.e. the faculty of correctly evaluating the potential losses and the associated occurrence probability, is an important condition of the insurability of a risk because it allows the use of actuarial methods for pricing insurance contracts. However, our societies are confronted with risks which do not confirm this condition, as is the case for extreme events, like natural hazards, environmental pollution or new technologies. The magnitude of the occurrence probability of the event is difficult to estimate, especially due to the non-availability of historical records, changing environments and new regulations. On the insurance markets, insurers have to incorporate this uncertainty in the premium estimation, but the demand can respond differently, and the way insureds will react to extreme events could cause disruption of insurance markets.

The decisions concerning these events are not taken in a risky environment where it is possible to define precise probabilities for the events, but in an uncertain environment where the information is not complete, namely an ambiguous situation. The subjective expected utility theory (Savage 1954) allows to treat a decision under ambiguity as a decision under risk, with a subjective probability distribution replacing the objective one (known in the precise environment). However, many works have shown that the notions of risk and ambiguity are treated differently (Ellsberg, 1961). This distinction has led to the separation between risk and ambiguity aversions. Furthermore, people seem to behave differently according to the source of ambiguity, separating here attitudes toward imprecision and conflict. Imprecision refers to a situation in which the information is consensual but imprecise; conflict refers to a situation of disagreement between experts. Smithson (1999) define conflict aversion as the fact that individuals prefer a consensual information over a controversial one. He explains that conflicts are perceived as less credible and trustworthy. This chapter intends to understand decisions regarding the insurance demand for extreme events coping with risky, imprecise and conflicting situations.

Insurance markets represent a promising context for empirical studies as the decisions deal with risk estimation. Hershey and Schoemaker (1980) highlight an insurance context effect, risk aversion being stronger in a real environment rather than in non-contextual lotteries. In addition, extreme risks lead to different behaviors than more common risks. Hershey and Schoemaker (1980) observe an overestimation of low-probabilities and an underestimation of large-probabilities, revealing that fair insurance should be more attractive for low probability risks, which is consistent with Kahneman and Tversky's (1979) prospect theory. However, individuals prefer purchasing insurance for large-probability small-loss events, rather than low-probability high-loss events (Slovic et al, 1977). The possibility of learning over time being limited, the occurrence probability estimation cannot always be adjusted. Individuals have a short term vision and prefer taking protection against most likely losses. Actually, bimodal behaviors are found in other empirical studies (Kunreuther, 1978; McClelland et al, 1993; Schade et al, 2004), revealing that people are either scared of extreme risks and pay a premium well in excess of the expected loss, or ignore them completely and do not insure. An explanation could be that individuals appreciate the likelihood of rare events contingent on their past experience (Kahneman et al, 1982). Then, insurance decisions do not only lean upon the need for protection through an arbitrage between the costs and benefits, and observable characteristics can help understand the underlying factors.

Furthermore, insurance decisions also vary in presence of ambiguity. When adding ambiguity, Schade et al (2004) observe a higher number of people willing to insure and large ambiguity aversion in the willingness to pay. Hogarth and Kunreuther (1985) find ambiguity aversion for low-probability events, but ambiguity preference for large-probability events. In a similar fashion, Kunreuther et al (1993) reveal that insurers also exhibit ambiguity aversion and demand a higher premium when the probability is ambiguous. However, these papers include ambiguity through comments explaining the uncertain situation around a best estimate, the ambiguity source is not defined. Di Mauro and Maffioletti (2001) study the impact of different definitions of ambiguity on the willingness to buy insurance. They distinguish the best estimate [1], the interval of probability, and the set of probability; but they do not notice major differences between the three representations (and they do not cope with extreme events). Cabantous (2007) and Cabantous et al (2011) reveal that insurers are sensitive to the ambiguity source. They test for imprecision aversion

1. The subjects were provided with a probability and were told that this was the best estimate available.

(Ellsberg, 1961) characterised by a consensual information that the true value of the probability ranges within an interval, and for conflict aversion (Smithson, 1999) when multiple sources of information lead to a disagreement on the value of the probability. They find that insurers exhibit stronger conflict aversion than ambiguity aversion, i.e. insurers dislike conflicting information and prefer consensual information. In addition, insurers seem to be slightly risk averse but highly ambiguity averse. These papers study non-contextual lotteries or insurance supply, but it seems that there is no paper analyzing insurance demand, especially of the general public, dealing with imprecision and conflict.

The analysis of insurance demand behaviors allows to compare the results for both sides of the market (insureds and insurers). Indeed, in a free market, supply has to meet demand. If the insurers only accept a very high premium for extreme risks under ambiguity (Cabantous et al, 2011), is there a demand for coverage for these same risks? People might not be as ambiguity averse, and therefore a market does not necessarily exist. How does the insurance demand for ambiguous risks stand in comparison to insurance demand for well-known risks? Is it possible to explain the insurance demand from the risk characteristics and the socio-demographic factors? How do individuals perceive imprecise and conflicting situations in extreme event risks? This chapter aims at producing new results on risk and ambiguity perceptions in relation with individual observable characteristics. The main objective is to reveal insurance demand behaviors, separating the attitudes toward risk, imprecision and conflict; and to find a set of determinants for these behaviors, based on socio-demographic characteristics. This chapter is part of a larger project including the behavioral study of insurance professionals in order to provide new insights on the insurance markets of extreme and ambiguous risks.

A questionnaire was administered to a large representative sample of the French population in order to put in relation insurance demand with socio-demographic characteristics. The final sample replicates the structure of the French population based on quotas from the last census report. Respondents had to give their willingness to pay for an insurance contract covering a low-probability risk and under a specific information type (risk, imprecision or conflict). Imprecision, here, refers to a situation in which the information is imprecise and consensual (experts agree on a vague estimate); and conflict refers to a situation in which the information is precise and controversial (experts disagree but each have a precise estimate). Subjects had the choice between buying insurance and revealing their maximum insurance premium, and not buying insurance and risking the loss.

The main results were as follows. Firstly, the decision to insure and the decision of the insurance premium portray two different actions with specific determinants. In particular, 25% of the respondents refuse to buy insurance and that decision can be explained by the age, the education level, the insurance claims and the past experience linked to extreme events. Secondly, risk and ambiguity lead to different behaviors. The results show that people are more willing to buy insurance and to pay a higher premium in the presence of risk than in the presence of ambiguity. They do not exhibit ambiguity averse behaviors that we expected, because they consider ambiguous situations as being inferior. Furthermore, people show a lack of confidence in the insurance markets, they have doubts about the reimbursements in case of a loss event. Thirdly, respondents exhibit conflict aversion. They would pay a higher premium under conflict than under imprecision, which reveals a preference for consensual information.

The chapter is structured as follows. The second section summarizes the main points of the literature on decision making under ambiguity from a theoretical point of view. The third section introduces the predictions and the experimental design of the survey. The fourth section presents the survey results, divided between the insurance decision per se and the willingness to pay, as well as the respective determinants of each decisions. In concluding, the chapter discusses the results relative to the mistrust into the insurance industry, and raises questions for further research.

2.2 Insurance demand under risk and ambiguity: some theoretical background

The expected utility model (EU) of von Neumann et Morgenstern (1947) has long been the main model for preferences representation under risk. It has been extended in the subjective expected utility (SEU) model proposed by Savage (1954), which allows to model a decision under ambiguity as a decision under risk, with a subjective probability distribution replacing the objective one. It assumes that each decision maker is able to have a precise idea of the probability distribution, even if it is subjective. However, the axioms are not always verified (Ellsberg, 1963), and the SEU model is not able to separate risk and ambiguity attitudes. Therefore, several models have been proposed to represent the preferences according to the available information.

In this part, we give some basic results on the willingness to pay for full coverage under three different information types (risk, imprecision and conflict) in a simple, two-states of nature insurance problem. Consider an individual with an initial wealth w who faces a risk of loss l. $S = \{L; \overline{L}\}$ is the state space with $L = \{Loss\}$ and $\overline{L} = \{No\ loss\}$. The outcome space $\mathscr{X}$ represents money and a decision is a couple $(a; b)$ where a is the individual's wealth if a loss occurs and b if no loss occurs. Then, two main decisions can be made (see Figure 2.1):

- The decision maker can decide not to buy insurance : $f = (w - l; w)$. The outcome of decision f depends on the probability distribution of loss between the two states.
- The decision maker can decide to buy full insurance at a premium π : $g = (w - \pi; w - \pi)$. The outcome of decision g is not impacted by the states of nature.

The individual evaluates decisions based on their preferences and beliefs of the risk characteristics. Let V be the value attached to these decisions. Then, the decision maker will prefer a decision over another by comparing $V(f)$ and $V(g)$. We will contemplate different functional forms for V. For all of them the decision g, which entails no exposure to any uncertainty, will be evaluated by $V(g) = u(w - \pi)$, where $u : \mathscr{X} \longrightarrow \mathbb{R}$ is a monotonic, increasing and concave utility function over outcomes. Furthermore, we are interested here in the maximum premium the individual is willing to pay for full coverage, i.e. the premium which makes one indifferent between buying and not buying insurance: π such that $V(f) = V(g)$.

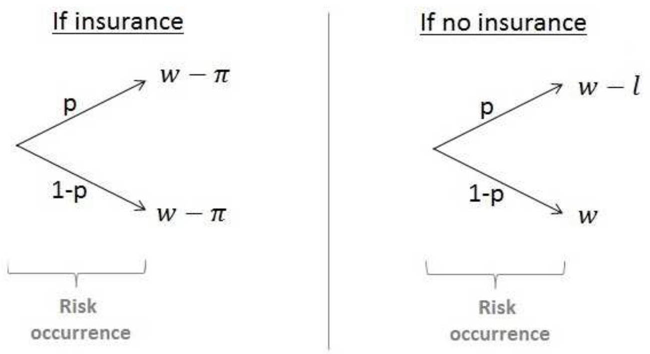

Figure 2.1: Outcome depending on the insurance decision and the state space

2.2.1 Insurance decision for well-estimated risk

In situations of precise risk, the decision maker has enough information to precisely estimate the probability distribution $(p\,; 1-p)$, where p is the probability of state L and $(1-p)$ the probability of state $\overline{L}$. With EU preferences, the value of decision f is:

$$V_{EU}(f) = pu(w-l) + (1-p)u(w)$$

The willingness to pay π for full coverage is the solution of $u(w-\pi) = pu(w-l)+(1-p)u(w)$. If the utility function is concave, reflecting diminishing marginal utility and risk aversion under EU, then, from Jensen's inequality, we have :

$$u(w-pl) > pu(w-l) + (1-p)u(w) \Leftrightarrow \pi > pl$$

Therefore, for risk averse individuals, the maximum premium they are willing to pay is strictly higher than the expected loss (pl). Furthermore, there exists only one π that maximizes $u(w-\pi) = V_{EU}(f)$ (Mossin, 1968). With EU preferences and concave u: $\pi_{EU} \in \,]\, pl\,; l\,]$. For risk neutral individuals (u is linear), the willingness to pay is the expected loss ($\pi = pl$). With SEU preferences, the result is similar except that the probability p is subjective.

2.2.2 Insurance decision under ambiguity

In situations of ambiguous risk, the decision maker has an imprecise knowledge of the probability distribution. The information is defined as a set P of probability distributions in which lies the true probability. In our insurance problem, $P = \{(p; 1-p)|p \in [p_{min}; p_{max}]\}$, the decision maker only knows that the probability of loss ranges between p_{min} and p_{max}. The actuarial expected probability is equal to $p = \frac{1}{2}(p_{min} + p_{max})$. In this way, the decisions under ambiguity can be compared with the decisions under risk.

Several models have been proposed in order to model ambiguous situations. In particular, the maxmin expected utility ($MaxMinEU$) model of Gilboa and Schmeidler (1989) considers that the decision maker evaluates a decision by computing its minimal expected utility on a subjective space state. For a decision f:

$$V_{MaxMinEU}(f) = \underset{p \in P}{Min} E_p u(f)$$

With $MaxMinEU$ preferences, our decision maker will only take into account the worst probability distribution, i.e. the highest loss probability: $V_{MaxMinEU}(f) = p_{max}u(w - l) + (1 - p_{max})u(w)$. Then, $V_{EU} > V_{MaxMinEU}$, a risky situation is always preferred to an imprecise one when p is the center of the interval $[p_{min}; p_{max}]$. Furthermore, in terms of willingness to pay, π is the solution of $u(w - \pi) = V_{MaxMinEU}(f)$. A risk averse individual will have a maximum premium of $\pi_{MaxMinEU} > p_{max}l$. A risk neutral individual will be willing to pay exactly $p_{max}l$.

In case of growing ambiguity, the probability set becomes $P' = \{(p; 1 - p)|p \in [p_{min} - \epsilon; p_{max} + \epsilon], \epsilon > 0\}$, and the maximum premium a risk averse individual will be willing to pay will be at least $(p_{max} + \epsilon)l$, as the highest possible loss is growing.

The alpha maxmin expected utility model ($\alpha MaxMinEU$) of Ghirardato et al (2004) allows to generalize the $MaxMinEU$ model in taking into account both the minimal and the maximal expected utility [2]. In addition, the model with second order beliefs (Klibanoff

2. With $\alpha MaxMinEU$ preferences, $V_{\alpha MaxMinEU}(f) = \alpha[p_{max}u(w - l) + (1 - p_{max})u(w)] + (1 - \alpha)[p_{min}u(w - l) + (1 - p_{min})u(w)]$, and therefore the maximum insurance premium the decision maker is

et al, 2005) assumes that the individual has a set of beliefs over P that measures how much they weight the possibility of $p \in P$ being the correct value[3].

However, in our insurance context, the information is imprecise but objective. If we assume the set P of $MaxMinEU$ to be objective information, the decision maker exhibit extreme ambiguity aversion. It is more appropriate to use a model that captures objective imprecise information (Gajdos et al, 2008). In our special case with only two states of nature, this model is similar to $\alpha MaxMin$. Gajdos et al (2008) ($GHTV$) represent preferences in taking a convex combination of the minimum expected utility with respect to all P, and the expected utility with respect to a precise p in P. Therefore, a decision f can be evaluated as follows:

$$V_{GHTV}(f) = \alpha \underset{p \in P}{Min} E_p u(f) + (1-\alpha) E_p u(f)$$

where α represents the attitude towards imprecise information., and $p = \frac{1}{2}(p_{min} + p_{max})$ is the actuarial expected loss. Then, the decision f is computed as:

$$V_{GHTV}(f) = \alpha[p_{max}u(w-l) + (1-p_{max})u(w)] + (1-\alpha)[pu(w-l) + (1-p)u(w)]$$

In terms of willingness to pay, π is the solution of $u(w-\pi) = V_{GHTV}(f)$, and we find a maximum insurance premium of:

$$\pi_{GHTV} > \left(\alpha p_{max} + (1-\alpha)\frac{p_{min} + p_{max}}{2}\right) l$$

Therefore, if $\alpha > 0$, the individual lends more weight on p_{max}: the premium is higher in an imprecise situation than in a precise one, which denotes ambiguity aversion: $V_{EU} > V_{GHTV}$ and $\pi_{EU} < \pi_{GHTV}$. If $\alpha = 1$, it is an extreme case where the decision maker only takes into account the worst case. If $\alpha = 0$, we get back to an EU representation.

willing to pay is $\pi > [\alpha p_{max} + (1-\alpha)p_{min}]l$, where α represents the attitude towards ambiguity

3. If the decision maker has a set of beliefs q_i over P: For $q_i \in [0;1]$ and $p_i \in [p_{min}; p_{max}]$, $V_{2OB}(f) = \sum_{q_i} q_i \Phi(\sum_{p_i}(p_i u(w-l) + (1-p_i)u(w)))$ and $V_{2OB}(g) = \Phi(u(w-\pi))$. Therefore, $\pi > [\sum_{q_i}\sum_{p_i} q_i p_i]l$.

In case of growing ambiguity, a risk averse individual will be willing to pay at least $\left(\alpha p_{max} + \alpha\epsilon + (1-\alpha)\frac{p_{min}+p_{max}}{2}\right) l$, which denotes growing ambiguity aversion if $\alpha > 0$. When an ambiguous situation becomes even more ambiguous, i.e. when the probability set P' enlarges to 2ϵ compared to P, the insurance premium increases of $\alpha\epsilon l$.

2.2.3 Insurance decision under conflict

Conflict occurs when several experts are consulted to estimate the probability distribution, but they disagree and each give their own estimate. Gajdos and Vergnaud (2009) have formalized decisions with conflicting information. They suppose that people exhibit conflict aversion, i.e. that they always prefer an imprecise situation over a conflicting one, they prefer information that is consensual and dislike when it is controversial. Furthermore, they prefer when the experts have opinions that are not too different from one another. Lets consider a decision maker facing conflict from two different experts giving respectively a set of probability distributions P and Q. Gajdos and Vergnaud (2009) represent preferences as follows:

$$\begin{aligned} V_{GV}(f) &= \underset{\gamma\in\Gamma}{Min}\left[\gamma\left(\underset{p\in\phi(P)}{Min}\, E_p u(f)\right) + (1-\gamma)\left(\underset{p\in\phi(Q)}{Min}\, E_p u(f)\right)\right] \\ \text{with}\quad \Gamma &= \left\{(1-\lambda)\left(\tfrac{1}{2};\tfrac{1}{2}\right) + \lambda(t;1-t) \mid t\in[0;1]\right\} \end{aligned}$$

ϕ is a linear mapping representing the subjective treatment of the information, Γ is a symmetric closed and convex subset that represents the attitude toward conflict, and λ ($\lambda \in [0;1]$) can be interpreted as a measure of conflict aversion. This model allows to take into account both attitudes toward imprecision and conflict, and can be read in two steps. First, the decision maker evaluates experts' assessment via ϕ and comes up with a belief for each assessments. Second, the evaluations are aggregated via the set Γ.

In our insurance context with conflict, let consider that one expert says that the loss probability is p_{min}, and the other says it is p_{max}. There is no imprecise information, i.e. P and Q are singletons respectively equal to p_{max} and p_{min}. Then, we only minimize on

Γ, and the value of decision f can be written as:

$$\begin{aligned} V_{GV}(f) = & \quad (1-\lambda)\left[\tfrac{1}{2}E_P u(f) + \tfrac{1}{2}E_Q u(f)\right] + \lambda \underset{t\in[0;1]}{Min}\left[tE_P u(f) + (1-t)E_Q u(f)\right] \\ = & \quad \underset{t\in[0;1]}{Min}\left[\left(\tfrac{1}{2}(1-\lambda)+\lambda t\right)E_P u(f) + \left(\tfrac{1}{2}(1-\lambda)+\lambda(1-t)\right)E_Q u(f)\right] \end{aligned}$$

where $E_P u(f) = p_{max}u(w-l)+(1-p_{max})u(w)$ and $E_Q u(f) = p_{min}u(w-l)+(1-p_{min})u(w)$. The willingness to pay is the solution of $u(w-\pi) = V_{GV}(f)$, that is:

$$\pi_{GV} > \left(\lambda p_{max} + (1-\lambda)\frac{p_{min}+p_{max}}{2}\right) l$$

And, in case of growing conflict, the insurance premium increases of $\lambda\epsilon l$, the premium being at least equal to $\left(\lambda p_{max} + \lambda\epsilon + (1-\lambda)\frac{p_{min}+p_{max}}{2}\right) l$.

λ captures the attitude toward the experts' disagreement. It reflects an arbitrage between the actuarial expected loss, which gives the same weight to both possible values of p and then do not differentiate the experts; and p_{max}, which allows to differentiate one expert over another. Gajdos and Vergnaud (2009)'s model supposes greater conflict aversion than ambiguity aversion ($\lambda > \alpha$), based on Smithson (1999)'s results, but also works if we assume the opposite.

According to these models of risk, ambiguity and conflict, the decision maker should always prefer a precise situation over an ambiguous one. Furthermore, the decision maker should always prefer an imprecise situation over a conflicting one. Therefore, in our survey, the maximum premium the individuals are willing to pay should be the lowest in presence of risk, and it should increase with imprecision and even more with conflict: $\pi_R < \pi_I < \pi_C$ with $R = \{Risk\}$, $I = \{Imprecision\}$, and $C = \{Conflict\}$.

2.3 Predictions and experimental design

2.3.1 Main predictions

The literature on decision making on insurance of extreme events brings to light that individuals behave differently in the presence of risk, imprecision and conflict, that they face difficulties in interpreting small probabilities and do not only reason based on the expected value. Insurance decisions are not yet entirely understood and it is interesting to analyze them by means of a large distributed survey. Considering the effects of ambiguity on insurance decisions dealing with extreme event risks is an important step in the conception of insurance and prevention strategies dealing with these risks.

This chapter reports a survey administered to a large representative sample of the French population. Respondents were asked to give the maximum premium they are willing to pay to purchase an insurance contract against a specific low-probability risk. Our main goal is to determine whether there is an insurance demand for ambiguous extreme risks, if the insureds exhibit risk, ambiguity and conflict aversion, and how the willingness to pay is related to the observable characteristics of the respondents. Let consider the following set of hypotheses, consistent with the theoretical literature, and investigating extensions of the empirical works of Smithson (1999) and Cabantous (2007).

H1: Individuals exhibit risk aversion.

- H1.1: Their willingness to pay for full insurance is always greater than the expected loss, i.e. the actuarial premium in case of full insurance. A risk neutral individual will be willing to pay exactly the amount of the expected loss.
- H1.2: They prefer the safer option and subscribe to an insurance contract. According to the theory, unless they perceive the probability as null, individuals will always decide to insure and have a positive willingness to pay.

H2: Individuals exhibit ambiguity aversion.

- H2.1: They are willing to pay a higher premium for a risk with ambiguous probability (imprecise or conflicting) than for a comparable risk with precise probability.
- H2.2: They exhibit growing ambiguity aversion. When the ambiguity gets larger, their willingness to pay for insurance increases.

H3: Individuals behave differently according to the source of ambiguity : they exhibit conflict aversion.

H3.1: They are willing to pay a higher premium for a risk with conflicting probabilities than for a comparable risk with imprecise probability.

H3.2: They prefer a consensual information over a controversial one. They find experts as less trustworthy when they disagree.

2.3.2 Motivation and survey questions

The survey is based on Kunreuther et al (1993), Cabantous (2007) and Cabantous et al (2011), but applied to the insurance demand. In these papers, insurers face ambiguous and extreme event risks. They have to indicate if they are willing to underwrite the risks and, if they do, what is the minimum premium they would accept to underwrite the risk. In our survey, we ask similar questions to individuals in order to determine the behaviors of insureds. They have to give the maximum premium that they would pay to transfer the risk to the insurers. The individuals have to imagine an insurance context in which a risk manager of a big company calls upon two experts in order to determine the true value of the occurrence probability that a windstorm risk would damage their buildings. The information given by the experts can take three forms:

– In a risky situation, the occurrence probability can be precisely estimated. The experts come to a consensus and agree on a unique and precise probability : p
– In an imprecise situation, it is impossible for the experts to narrow the occurrence probability to a precise estimate. Therefore, the experts agree that the occurrence probability ranges within an interval : $[p_{min}; p_{max}]$
– In a conflicting situation, the experts might not have the same information or hypotheses. Therefore, they disagree and each expert gives their own estimate of the occurrence probability : either p_{min} or p_{max}

In addition, the survey tests for growing imprecision and growing conflict aversion. In that sense, subjects are requested to respond to two other questions related to two

Table 2.1: Five questions for three different information types

	Questions	*Information type*	*Occurrence probability*
1	**Risk**	consensual and precise	1.25%
2	**Imprecision**	consensual and imprecise	Between 0.5% and 2%
3	**Growing imprecision**		Between 0.1% and 2.4%
4	**Conflict**	conflictual and precise	0.5% according to an expert, 2% according to another one
5	**Growing conflict**		0.1% according to an expert, 2.4% according to another one

other ambiguous situations. In a growing imprecise situation, the experts agree that the probability range within a larger interval $[p_{min} - \epsilon; p_{max} + \epsilon]$. In a growing conflicting situation, the experts disagree and each expert gives their own estimate: either $p_{min} - \epsilon$ or $p_{max} + \epsilon$.

In order to be able to compare the questions, the precise and consensual estimate of the risky situation (p) is the mean[4] of p_{min} and p_{max}, and of $p_{min} - \epsilon$ and $p_{max} + \epsilon$, corresponding to ambiguity neutrality in the $\alpha MaxMin$ model. We assume that the loss amount estimation is not an issue to the experts (100,000€), hence the expected loss is always the same (1,250€). Ultimately, the respondents answer five questions, which are summarized in Table 2.1, with the complete summary found in the Appendix. After each question, they have the possibility to write a comment in order to explain their choice. These comments will be included in the analysis.

The behaviors under risk and ambiguity can vary depending on the scenario. In addition to the natural risk of windstorm, questions on an environmental liability risk scenario based on de Marcellis (2000) were also asked. This scenario introduces a man-made risk of pollution that could trigger the third-party liability of a company. We used the same probabilities as in the windstorm risk scenario, but with a higher loss amount (2,000,000€), thus the expected value is 25,000€. The questionnaire was divided into three parts. One part contained the windstorm risk scenario and the other part the environmental liability

4. Contrary to Cabantous et al (2011), we use the arithmetic mean and not the geometric mean. In their paper, they use p equal to 1%, the geometric mean of $p_{min} = 0.5\%$ and $p_{max} = 2\%$.

risk scenario. For both these parts, there were ten questions over all. The last part asked about the respondents' characteristics (e.g sex, age, job, level of education, income level, marital status, region of living), insurance (insurance claims in the past three years, amount, type), and extreme events (past experience concerning windstorm and pollution risk, perception of the terrorism risk level in their country). The order of the scenarios and the order of the questions inside each scenario was randomized in order to control for potential order effect.

2.3.3 Sampling plan and respondents

The survey was administered, with the assistance of a marketing institute, through a web-questionnaire. In this way, the experiment took place in a free environment, and individuals can reveal their preferences without constraints. The subjects were compensated with points entitling them to vouchers. There were no other incentives expect this flat gain, but we presume that individuals know how they would behave in these situations that have a practical orientation. The survey was completely anonymous, thus the respondents did not have any profit to disguise their preferences.

The questionnaires were sent to individuals in order to have a final sample matching certain characteristics of the French population. The quotas were calculated from the 2006 census report of the French National Institute of Statistics (INSEE), on sex, age, regions of France, and socio-economic groups. Experimental papers are usually based on responses from student subjects who have an economic background and therefore they give particular attention to the level of probabilities. However, our experiment is based on a representative sample of the French population. This "real population" does not necessarily have any background in economics or probability, and their responses might not be the same as students. The final sample consisted of 1505 questionnaires. We excluded 33 individuals [5] (2.19% of the sample). The analyzed sample of 1472 responses still portrays the French population [6], and we will analyze the data with the Stata program, version 11.

5. These are individuals explicitly demanding not to analyze their responses because they did not know how to answer (4 individuals), or they are individuals willing to pay a premium greater than the highest possible loss (29 individuals), revealing an obvious misunderstanding or misreading of the questions.

6. Of the 1472 respondents, 49% were male and 51% females. The youth (between 18 and 24) represent 14% of the population. The 20-34 and the 35-49 year olds account respectively for 22% and 34% of the population, the 50-59 for 21% and the 60-65 for 9%.

Table 2.2: Summary statistics of the windstorm risk scenario

	Risk (R)	*Imprecision (I1)*	*Growing imprecision (I2)*	*Conflict (C1)*	*Growing conflict (C2)*
Nb of refusals	377	386	422	404	468
% of refusals	25.5%	26.2%	28.7%	27.4%	31.8%
Mean premium(€)	1 920	1 632	1 846	1 763	1 709
Mean/EL	1.54	1.31	1.48	1.41	1.37

Note: EL means Expected Loss, defined as the average probability multiplied by the total loss amount: EL=1 250€, 1.25% chance of losing 100,000€.

Table 2.3: Summary statistics of the environmental liability risk scenario

	Risk (R)	*Imprecision (I1)*	*Growing imprecision (I2)*	*Conflict (C1)*	*Growing conflict (C2)*
Nb of refusals	325	330	374	331	437
% of refusals	22.1%	22.4%	25.4%	22.5%	29.7%
Mean premium(€)	14 625	14 726	15 374	14 176	13 517
Mean/EL	0.58	0.59	0.61	0.57	0.54

Note: EL=25,000€: 1.25% chance of losing 2,000,000€.

Table 2.4: Statistical significance between the questions

	R - 1	R - A	I1 - C1	I2 - C2	I1 - I2	C1 - C2
CAT	$>$***	$>$**	$<$**		$<$***	
RC	$<$***	$>$*	$>$*	$>$**		$>$*

*** $p<0.01$; ** $p<0.05$; * $p<0.1$

Note: This table reports the significance of Student tests. The first column test for risk aversion, i.e. if the mean normalized premium under risk is greater than one. The second column test for ambiguity aversion, i.e. if the premium under risk is lower than the premium under ambiguity. Table 2.5 in Appendix shows examples of tests with the Stata 11 software.

2.4 Results: Two distinct insurance decisions

The literature on insurance decisions suggests that both the insurance decision and the decision of the insurance premium depend on the risks characteristics (occurrence probability and loss amount), the insurance contract (context and terms of the contract), the preferences of individuals, and socio-demographic factors. However the underlying variables are not the same in both decisions. Therefore, in our analysis, we separate the insurance decision per se from the amount of insurance premium, as in the article by Guiso and Jappelli (1998).

2.4.1 The insurance decision and its determinants

2.4.1.1 The impact of ambiguity sources on the decision to insure

We focus here on the insurance decision per se, that is whether people buy insurance or not. Buying insurance at a premium greater than the expected loss is a signal of risk aversion. Refusing insurance do not reveal risk averse behaviors, in the sense that the individual is willing to accept the whole consequences of the event. Table 2.2 and Table 2.3 reports respectively the number of refusals for the windstorm and the environmental liability risk scenario. The percentage of individuals refusing to purchase insurance ranges between 25.2% and 31.8% of the sample for the windstorm risk scenario. The other scenario gives similar results. These results go in the opposite direction of hypothesis H1.2 which assumed that it was hard to imagine not buying insurance, even at a low price, considering the large possibility of loss. The refusal to purchase insurance can be explained by the fact that people are risk lovers, or because they underestimate the occurrence probability of the risk, believing it is null. This is related to the fact that individuals do not understand probabilities, especially low probabilities, and then often ignore the information when making decisions. Furthermore, individuals are often myopic: if they have paid insurance for a few years and did not collect on their policy, they see insurance as a bad investment and refuse to renew their contract.

Other explanations were found reading the comments [7] of the respondents, especially the fact that people do not feel concerned about the risk so they do not fear it. Furthermore, an important factor of refusing insurance seems to be related to a lack of trust in the insurance market, and in particular of insurers. Indeed, lots of negative comments reveal that individuals dislike insurance companies and they do not trust the will of insurers to pay claims. Some people wrote comments explaining that insurers intentionally overestimate occurrence probability in order to ask for higher premiums. Other comments complained about how insurers do not pay back as much as they promised once the risk occurs. Therefore, the insurance industry seems to be perceived negatively in France. [8]

Moreover, the refusals grow with ambiguity. The percentage of respondents not buying insurance increases in the imprecise situation and even more in the situation of growing imprecision for both scenarios. This progression of refusals is even stronger with conflict, and reaches almost one third of the sample with growing conflict. Therefore, people seem to dislike ambiguity in insurance and refuse to insure. They seem to place more credence on p_{min} and $p_{min} - \epsilon$, considering these low estimates as null. Indeed, people are more willing to trust the expert expressing almost certainty (an estimate close to 0) than the one expressing more riskyness (Baillon et al, 2011). This is also linked to the problem of confidence in insurance markets. People prefer taking the risk thinking the probability is null, rather than purchasing insurance and trusting experts who may be wrong. This rejection of experts' estimates is greater in conflict than in imprecision, which confirms hypothesis H3.2 that people prefer consensual information and tend to avoid conflicts.

2.4.1.2 The impact of observable characteristics on the decision to insure

Observable characteristics influence the decision to insure. When running independence tests (chi^2 tests), several variables appear to be significant. The individuals refusing insurance are mostly the youth. Between 18 and 25 years old, 30% do not buy insurance

7. In the survey, 30% of the respondents wrote comments that we divided into four qualitative categories: the one finding the survey interesting and being enthusiastic, the one giving neutral opinions or suggestions, the one finding the survey difficult, and the one criticizing insurance markets.

8. Some comments are the following: "I refuse to buy insurance because insurers never indemnify us.", "Insurance are too expensive and insurers are thieves. In case of claim, we never fall within the clauses", "Polluting companies are generally exempted from responsibility, and insurers don't pay cleanup bills", etc.

in comparison to 19% for the more than 50. The number of refusals are higher for the lower socio-economic groups [9], those persons with little or no level of higher education, those with low incomes and bachelors. Furthermore, more people are willing to insure if they have claimed on insurance damage within the last three years, and if they or their neighbours have experienced a windstorm event in the past. Finally, more than 60% of the respondents that criticized the insurers would not buy insurance.

In Table 2.6 of Appendix, we report a first Probit regression of the binary decision of buying insurance or not for the windstorm risk scenario under risk. The probability of buying insurance positively depends on age and on education level. Being between 25 and 49 years old, in comparison with the youngest, increases the probability to insure by 23%. Being older than 50 increases the probability to insure by 32%. In terms of marginal effect, the predicted probability of buying insurance is 7% for the 25-49 and 9% for people older than 50. In addition, having a higher degree (Masters degree or Ph.D.) increases the probability of purchasing insurance by 30% in comparison to having no degree. People with higher education are more willing to insure than people with less education. One could think that it is related to the level of income (Petrolia et al, 2011), however income is not a significant variable in the insurance decision.

According to Kunreuther (1984), refusing insurance cannot be explained by income, but by the deny of the exposure to catastrophe. In this way, the Probit estimates show that past experience [10] with windstorms have a significant positive effect on the demand for insurance. In addition, the people that claimed on insurance damage within the last three years are also more willing to buy insurance. These variables are related to the regions of France, the north being more impacted by windstorms than the south. Then, the demand for insurance is higher for residents in this part of France. Finally, the perception of the terrorism risk is a significant factor on the insurance decision. This variable should not have a great impact as it is related to the formation of beliefs and not to information processing.

9. The socio economic groups can be divided into two main groups according to the INSEE classification: an upper group that is supposed to have a high purchasing power, and a lower group with poor purchasing power.

10. The fact that the respondent or its neighbors and family have experienced a risk of windstorm.

Table 2.7 of Appendix presents another Probit regression with the fixed effect on the type of risk (natural catastrophe or man-made event), and the type of information (risk, imprecision, conflict). This regression reports much more significant estimates, and the pseudo R^2 doubles. The regression shows that the insurance decision depends on risk and information types, past experience (with the risk and with insurance) and socio-demographic variables. Situations of risk and natural events are more likely to be insured than situations of ambiguity and man-made events. Furthermore, the individuals who have experienced a windstorm risk, who have claimed on insurance and who perceive the terrorism risk as high are more willing to get insured. Gender, level of education and of income positively influence the decision to purchase insurance. The youngest (under 25) are less likely to buy insurance compared to the older ones, but the effect decreases from 35 years old and fades at 60 years old. Being between 25 and 34 years old is correlated to living a common life. Having more than two children, which is correlated with the fact to be married, decreases the likelihood to buy insurance. This can be explained by an effect to smooth consumption and investments over the members of the family. These results are in line with studies on insurance factors. Guiso and Jappelli (1998) find that the insurance decision depends on the level of education, the income, the region, and the size of the city. In addition, Petrolia et al (2011)'s factors of the insurance decision are the past experience, the region, the eligibility for disaster assistance, the credibility of insurers, the risk aversion, and the income.

To summarize, it is possible to find a set of characteristic variables that helps to understand the insurance decision. That decision is not only an arbitrage toward the risk specifics. Refusing insurance reveals a lack of confidence in the French insurance industry, a result that might not be the same in other countries where the risk culture is different. The socio-economic characteristics (gender, age, level of education, level of income, marital status), as well as the experience in terms of insurance and extreme risk events, significantly impact the decision to insure. However, we will see in the next section that the factors are not the same for the willingness to pay, which seems to be a complex decision.

2.4.2 The insurance willingness to pay and its determinants

2.4.2.1 The impact of ambiguity sources on the willingness to pay

We focus here on the willingness to pay for insurance, i.e. on insurance amounts people are willing to pay for insuring against specific risks, and in particular on the behaviors in the windstorm risk scenario [11]. Table 2.2 reports the means of premium and of normalized premium of the respondents buying insurance [12]. A normalized premium equal to one denotes an insurance premium equal to the expected loss, and then a risk neutral attitude. We see that premiums are significantly higher than the expected loss for the five questions. This fact corroborates hypothesis H1.1 that people exhibit risk aversion (Kunreuther, 1978; McClelland, Schulze, and Coursey, 1993). The premium distribution shows a strong asymmetry to the left, the skewness being on average around 6.20. Almost 70% of the population buying insurance is willing to pay a premium lower than 1,000€, i.e. 0.8 in terms of expected loss. This taste for risk of certain respondents might be the consequence of misunderstanding risk characteristics or the importance of other factors. People do not only take a decision based on probability. Indeed, some people have indicated in the comments that they are not familiar with probabilities. Previous studies have been conducted on student subjects who had greater familiarity with probability.

The results show that the mean premium with precise information is always greater than the one with imprecise or conflicting information. Student tests [13] confirm that these results are robust. Therefore, H2.1 is rejected because people do not exhibit ambiguity averse behaviors: they are willing to pay a higher price in situation of risk than in situation of ambiguity. This finding does not go in the sense of the usual literature supposing ambiguity aversion in low probability losses. However, the popular hypothesis of ambiguity aversion has met some mixed validations. Several empirical evidence suggest that ambiguity preference in low probability losses exists (Einhorn and Hogarth, 1986; Cohen

11. As we will see later, the results of the windstorm risk scenario are more robust and more significant than the ones in the environmental liability scenario

12. These premiums are calculated based on the respondents buying insurance, then the samples are not exactly the same. However, taking the same sample reduce the number of observations and produces exactly the same results.

13. The p-values of the t-tests on the differences between risk and imprecision or conflict are null.

et al, 1987; Dobbs, 1991; Kuhn, 1997; Ho et al, 2002; Chakravarty and Roy, 2009; Wakker, 2010, on page 354; ...). Therefore, it is not clear yet how people respond to ambiguity in losses. In particular, Sarin and Weber (1993) study the effect of ambiguity on the price in market experiments, and find that the price for ambiguous assets is lower than the price for unambiguous assets. They explain it by the fact that subjects consider an ambiguous assets as inferior, and thus they are willing to pay less for it. Within an insurance context, Wakker et al (2007) find ambiguity seeking in the willingness to take insurance, because people prefer the more familiar option and that normal decisions are made without extra statistical information.

The context of growing ambiguity lead to different results. Regarding the attitudes toward imprecision, the mean premium increases in the situation of growing imprecision. People are willing to pay a higher price when the interval of probability gets larger [14]. Therefore, they exhibit growing imprecision aversion, which confirms hypothesis H2.2. However, regarding the attitudes toward conflict, the mean premium in situation of conflict is higher than the one in situation of growing conflict. Therefore, people exhibit a certain taste for growing conflict [15]. The two situations of conflict have been clearly seen as different, given the number of refusals (see previous section). Hypothesis H3 suggests that the attitudes toward imprecision and conflict are different. The results show that the mean premium with imprecise information is significantly lower than the one with conflicting information. Thus, hypothesis H3.1 is confirmed. However, the opposite is true between growing imprecision and growing conflict even if the difference is not statistically significant. The weight given to the lowest estimate is higher in a situation of growing conflict than in a situation of growing imprecision (Baillon et al, 2011). People behave in different ways in the presence of conflict and imprecision. The differences between the five questions are robust within the sample. We tested several subgroups with specific characteristics to determine if one subgroup had completed the whole set of hypotheses cited in section 3.1. We found similar results within each group.

14. The p-value of the t-test on the difference between imprecision and growing imprecision is 0.062.
15. However, the Student test on the mean difference between conflict and growing conflict is not significant (p-value of 0.135), but the test on the median difference is significant (p-value of 0.007).

Attitudes toward imprecision and conflict are different. They pay a higher premium in the situation where experts disagree, however fewer people are willing to insure. People exhibit conflict aversion, they prefer consensual information and dislike conflicting one. Smithson (1999) and Cabantous et al (2011) explain that people attribute imprecision to the task difficulty and conflict to the incompetence of the experts. The differences between these two ambiguity sources can come from the unknown and unknowable informations of Chow and Sarin (2002) [16]. Here, imprecision is related to the unknowable information and conflict to the unknown information. Chow and Sarin (2002) find that people prefer when probabilities are precise (known information) and they feel insecure when they are ambiguous (unknown information), because they think someone else possesses the information. This feeling of relative ignorance can be found in the higher number of refusals in the presence of conflict. Furthermore, they prefer unknowable information over unknown information. According to them, uncertainty is more acceptable when the information is not available at all. In this sense, it can explain why people prefer imprecise information (unknowable) over conflicting one (unknown). Meanwhile, a known information is always preferred. That is why people are willing to pay a higher premium under risk. They consider ambiguous situations as being inferior (Sarin and Weber, 1993).

With controversial information, people think that the disagreement is due to the expert's incompetence, or to the insurer's will to increase premiums (linked to the negative perception of insurance in France). The competence of an expert is related to their credibility. In the questionnaire, respondents had no information that could allow to differentiate the experts. Even in real life, the reliability of expert opinion is difficult to assess and decisions contain subjectivity. The behaviors and choices depend on the perceived reliability of the available information. This perception can change when conflict grows. Therefore, the expert almost claiming certainty (an occurrence probability almost equal to zero) could be preferred and overweighted in the decision (Baillon et al, 2011).

16. Chow and Sarin (2002) differentiate known, unknown and unknowable information. Known information refers to a precise situation. Unknown information refers to an ambiguous situation for which other people might have the missing information. Unknowable information refers to an ambiguous situation in which nobody knows the true value of the missing information.

Concerning the environmental liability scenario, the results are very different from the ones of the windstorm risk scenario (see Table 2.3). Surprisingly, the mean premiums are always lower than the expected loss: respondents do not exhibit risk aversion. Nearly 90% of the sample are willing to pay a premium lower than the expected loss. The rank of the questions are almost the same as for the windstorm risk scenario, except that the mean premium under risk is on the same level as the mean premium of the other questions. The premium distribution is much smoother, and the differences between the questions are not as significant [17]. Kahn and Sarin (1988) report that the context causes subjects in a consumer choice experiment to switch from being ambiguity averse to ambiguity seeking. For insurers, the type of peril also seems to affect the decision. Insurers charge higher premiums for earthquake and hurricane risks than for pollution and fire risks (Cabantous, 2007; Cabantous et al, 2011). In our results, the differences can be linked to behavioral differences due to the peril type (natural risk versus man-made risk), and/or to the larger total loss amount of the environmental risk that has been underestimated. People face difficulties to assess a risk with a total loss amount of 2 million euros. Furthermore, it is more difficult to imagine an environmental risk, which is less common and more specific to companies, than a windstorm risk.

In the comments, some individuals explicitly wrote that they will never face the environmental liability risk. Indeed, the risk of pollution is mostly relevant to companies. The scenario is highly hypothetical for individuals, and therefore individuals were requested to act in the capacity of a company. In this way, they do not only reason based on their own possible risks. Moreover, the problem of competence is much deeper, as comments reveal that they do not want to take the responsibility for that kind of decision. They prefer government intervention in case of extreme risks. Thinking about extreme risks is difficult and believing the consequences takes a cognitive effort. Appreciating such biases and reducing them through prevention and communication, is an important step.

17. The Student tests show weaker differences between the questions.

2.4.2.2 The impact of observable characteristics on the willingness to pay

The insurance premium decision seems to be correlated to observable characteristics, according to independence tests (chi^2) and analyses of variance (ANOVA). Especially, women are willing to pay on average a premium 25% higher than men. The premiums are also higher for the youth (less than 25 years old), the low socio-economic groups and the low incomes. In addition, individuals feeling the terrorism risk at a high level are willing to pay on average 2,400€ (1.9 in terms of expected loss); and the ones feeling that the terrorism risk is very low are willing to pay on average 1,000€ (0.8 in terms of expected loss). Regarding comments, the respondent criticizing insurance markets are willing to pay a very low premium (on average 220€, i.e. 0.18 in terms of expected loss).

Due to the censoring of the variable (refusals of insurance being premiums equal to 0), we ran a Tobit [18] model on the whole insurance demand decision. However, the sign pattern and statistical significance do not match those of the Probit model. Only two characteristics have a significant and positive influence on insurance demand on the whole: the fact that people have reported an insurance claim within the last three years, and the level of perception of terrorism risk. With only two significant variables, the insurance demand cannot be explained by observable characteristics. However, the Tobit model is an ordered regression and does not represent bimodality.

Indeed, there is a bimodality for a certain number of individuals [19]. Other models are needed to translate this possible effect. Nevertheless, it is not possible to find a set of significant variables explaining the entire insurance decision. Within an insurance context, there seems to be several attitudes toward risk, imprecision and conflict. Table 2.8 of Appendix reports the results of a regression on the willingness to pay (without the refusals of insurance). The coefficient of determination is quite low (5.6%), but we can observe some interesting features. The regression shows that the maximum insurance premium the individuals are willing to pay for insurance depends on the age, the socio-economic group, the level of education, the marital status, the number of children, and the income level.

18. The results of the Tobit model are not presented here due to their poor significance.
19. The people refusing insurance and the people demanding the highest premiums seem to have similar characteristics (youth, low socio-economic group, low income).

These variables have opposite effects than on the insurance decision, which denotes bimodal behaviors. In particular, we observe that the high socio-economic group, the married and the ones with more than two children, the ones with high educational and high income level will be more willing to purchase insurance and to pay a lower insurance premium. On the opposite, the others will be more willing not to buy insurance or at a relatively high premium. Therefore, insurance decisions depend on objective risk characteristics such as the type of risk and the probability of loss, the exposure, the terms of the insurance contract; on risk subjective perception (the terrorism perception in our case), and on individual preferences (Petrolia et al, 2011). The individual preferences are influenced by the demographic characteristics such as the age, the marital status, the number of children, the level of education, the income and the past experience (Guiso and Jappelli, 1998).

People do not only reason based on the risk characteristics. The general public constituent our sample does not necessarily understand probabilities and high amounts of losses. Some admit in the comments of not having any background in mathematics. People cannot always make an explicit trade-off between the expected benefits of buying insurance and the possible costs of taking the risk (Kahneman and Tversky, 2000). Furthermore, the presence of ambiguity makes it more difficult to choose, leading to either overestimating or ignoring small probabilities (Kunreuther et al, 2001). People face difficulties assessing an equivalence between ambiguous and non-ambiguous probabilities, or believing a very large amount of loss. The available information can be misunderstood.

Behaviors are affected by risk perception, itself distorted by cognitive biases and emotional factors such as pessimism and myopia. The level of perception of the terrorism risk, which is related to the formation of beliefs and not to the objective analysis of the available information, is always a significant variable in our models. This variable represents a proxy for pessimism and thus ambiguity aversion. Indeed, it depicts a constant psychological trait on different decisions. Furthermore, past experience concerning the risk is also a significant variable. People often purchase insurance following a disaster. They do not think that the best return on an insurance policy is no return at all. Most individuals consider that the event will simply not happen to them. It is a psychological bias toward short-term maximization instead of long-term planning (myopia). In addition, in France, catastrophe coverage is automatically included in a comprehensive home insurance contract (without even people knowing about it); and the government helps in case of major event. Then, a status quo behavior is not changing its insurance coverage. Therefore, insurance decisions represent a balance between intuition and more deliberate analysis.

2.5 Discussion of the insurance demand and the problem of confidence

The results have highlighted that one third of the population are willing to take the consequences of a low-probability event and does not buy insurance, and that is linked to lack of confidence in the insurance industry. The credibility of the insurance industry clearly affect the insurance decisions. The insurers' reputation appears to be an important factor of the insurance decision. Comments reveal a lack of trust in the insurance industry, and are highly correlated with the refusals of insurance. People do not insure because they think that the insurers will not reimburse them in case of a loss event. Petrolia et al (2011) tests for the credibility of insurance providers, i.e. the level of confidence in insurance company payouts that cover the full amount of claims[20]. They find a significant effect of that variable on the insurance decision: the individual not trusting insurers do not buy insurance. The bad reputation of insurers is part of the prejudice against the insurance industry, as written in Crocker and Tennyson (2002): *"The miserly proclivities of insurers when settling claims is legendary and occupies a place in the pantheon of business stereotypes along with the sharp horse trader and the obdurate banker."* (p.470).

In our regression models, if we include fixed effects on the comments individuals wrote in the open comment question, we find highly significant effect of the fact to criticize insurance. The Probit model reports an increase of the Pseudo R_2 from 7.09% to 7.95% and similar coefficients and significance levels than Table 2.7. The results show that the individuals criticizing the insurers are less likely to buy insurance, with the marginal probability being of -13.9%. It is the same in terms of premium level, the coefficient of individuals

20. The variable was 1 if no confidence, and 5 if full confidence. The average was 3.02.

criticizing insurance is highly significant and equal to -1.83, which goes in line with the fact that these people are less willing to pay for insurance.[21]

Insurance contract can sometimes be very complex and difficult to understand. The clauses and dispositions can be written in an ambiguous sense and people do not necessarily know to what extent they are covered by the policy (the risks, the condition, the assessment, the deductible,...). In case of loss, the claim cannot be accepted by the insurer, or not entirely, which create a distrust effect toward the insurers. Furthermore, the insurer can underpay the claims in order to increase their results, even if this practice is not legal. Crocker and Tennyson (2002) find that the insurer's optimal strategy of claim settlement is to systematically underpay the claims in order to mitigate fraud. Then, the insurer makes a trade-off between the underpayments and the desire to avoid the litigation costs of systematic underpayment. In this case, the "bad faith" of the insurer clearly create a distrust effect.

Taking back the previous theoretical settings where p is the occurrence probability of a risk, we can add a probability q of the insurer's default in the claim settlement, with $p < q$. This problem becomes a three-states of nature insurance problem, that takes into account both the uncertainties surrounding the risk and surrounding its reimbursement, as shown in Figure 2.2. In case of insurance, three cases can come up:

- The risk did not occur (probability $1 - p$), and the final outcome of the insured is $w - \pi$.
- The risk did occur (probability p), and the insurer fully covers the loss (probability $1 - q$). The final outcome of the insureds is $w - \pi$.
- The risk did occur (probability p), but the insurer did not reimburse the claim (probability q). The final outcome of the insureds is $w - \pi - l$.

21. We do not report the regressions' results here as it does not change the results from Tables 2.7 and 2.8, and as the possibility to write comments was an open question. Only 2.1% of the respondents have openly criticized insurance in the comments (29% have written a comment).

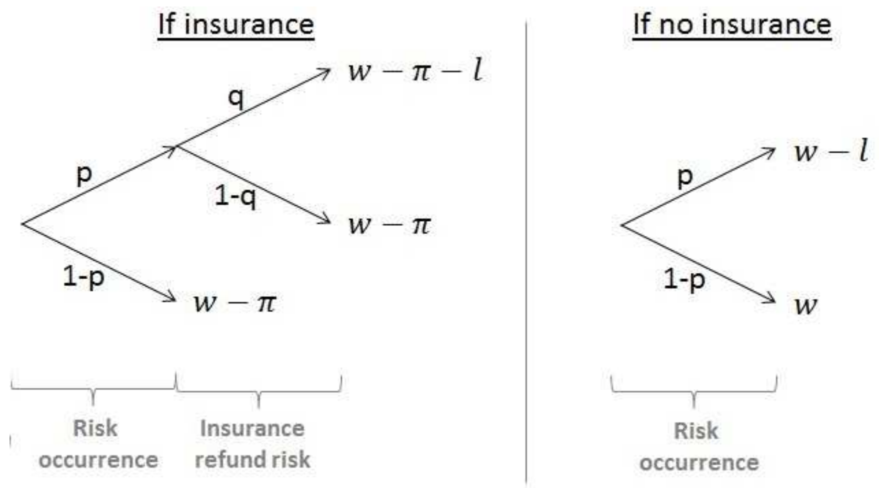

Figure 2.2: Outcome depending on the insurance decision and the state space

With EU preferences, the value of the decision f not to buy insurance and of h to buy full insurance are the following:

$$\begin{aligned} V_{EU}(f) = &\quad pu(w-l) + (1-p)u(w) \\ V_{EU}(h) = &\quad p[(1-q)u(w-\pi) + qu(w-\pi-l)] + (1-p)u(w-\pi) \end{aligned}$$

Then, we have: $V_{EU}(f) = V_{EU}(h) \Leftrightarrow F(\pi, q) = 0$, and we want to analyse the function $\pi(q)$ with $q \in [0;1]$. We can differentiate the function π with respect to q:

$$\frac{\partial \pi}{\partial q} = -\frac{\frac{\partial F}{\partial q}}{\frac{\partial F}{\partial \pi}} = -\frac{p[u(w-\pi-l) - u(w-\pi)}{-p[qu'(w-\pi-l) + (1-q)u'(w-\pi)] - (1-p)u'(w-\pi)}$$

Therefore, we have $\frac{\partial \pi}{\partial q} < 0$, which means that the maximal insurance premium is decreasing with the default probability q. Indeed, the higher the probability that the insurer won't pay the claims in case of loss, the lower the insurance premium people are willing to pay.

We know that, for u concave, $\pi(0) = \pi_{EU} > pl$ as previously shown, and $\pi(1) = 0$ as the insured will refuse insurance if she knows the claims won't be payed out. Then, we can conclude that it exists $q*$ such that, even if u is concave, $\pi(q) < pl$ for $q \in [q*; 1]$. The premium can be lower than the expected loss.

Under ambiguity with $GHTV$ preferences, the value of the decision f is the $V_{GHTV}(f)$ previously described, and $V_{GHTV}(h)$ is:

$$\begin{aligned} V_{GHTV}(h) = \;& \alpha\Big(p_{max}[(1-q)u(w-\pi)+qu(w-\pi-l)]+(1-p_{max})u(w-\pi)\Big) \\ & +(1-\alpha)\Big(p[(1-q)u(w-\pi)+qu(w-\pi-l)]+(1-p)u(w-\pi)\Big) \end{aligned}$$

In the same way than with EU, we have $V_{GHTV}(f) = V_{GHTV}(h) \Leftrightarrow F(\pi, q) = 0$ and we analyze $\pi(q)$, and we also find that $\frac{\partial \pi}{\partial q} < 0$. For u concave, we have $\pi(0) = \pi_{GHTV} > (\alpha p_{max} + (1-\alpha)p)\, l$ with $p = \frac{p_{min}+p_{max}}{2}$, and $\pi(1) = 0$. Therefore, it exists $q*$ such that, for all α and u concave, $\pi(q) > (\alpha p_{max} + (1-\alpha)p)\, l$ for $q \in [q*; 1]$.

Under conflict with GV preferences, the value of the decision f is the $V_{GV}(f)$ previously shown, and $V_{GV}(h)$ is:

$$V_{GV}(f) = \underset{t\in[0;1]}{Min}\left[\left(\frac{1}{2}(1-\lambda)+\lambda t\right) E_P u(h) + \left(\frac{1}{2}(1-\lambda)+\lambda(1-t)\right) E_Q u(h)\right]$$

where:

$$\begin{aligned} E_P u(h) = \;& p_{max}[(1-q)u(w-\pi)+qu(w-\pi-l)]+(1-p_{max})u(w-\pi) \\ E_Q u(h) = \;& p_{min}[(1-q)u(w-\pi)+qu(w-\pi-l)]+(1-p_{min})u(w-\pi) \end{aligned}$$

In the same way, we have $V_{GV}(f) = V_{GV}(h) \Leftrightarrow F(\pi, q) = 0$ and $\frac{\partial \pi}{\partial q} < 0$. For u concave, $\pi(0) = \pi_{GV} > (\lambda p_{max} + (1-\lambda)p)\, l$ with $p = \frac{p_{min}+p_{max}}{2}$, and $\pi(1) = 0$. Therefore, it exists $q*$ such that, for all α and u concave, $\pi(q) > (\lambda p_{max} + (1-\lambda)p)\, l$ for $q \in [q*; 1]$.

We have just shown that the insurance premium can be lower than the expected loss if the insureds believe that the insurers will not reimburse as expected, which means that there is a mistrust problem in the relationship between the insured and the insurer. Obviously, we have supposed that the insurer's default in the claim settlement (q) was precisely estimated, whereas q is more likely to be ambiguous.

However, the distrust toward the insurance industry can be counterbalanced and the reputation enhanced. Indeed, the results also show that more people buy insurance when they have reported insurance claims than when they have not. The people dealing with insurance are more willing to insure and to buy insurance at higher premiums. Therefore, there seems to be a difficulty to trust insurers before experiencing an insured loss. This effect is coherent with Michel-Kerjan et al (2011) who analyze under-insurance though the policy tenure of insurance contracts, i.e. the renewal over the years. They find that small claims over the years make people keep insurance longer because individuals realize the benefit of insurance and collect rapidly on their insurance contract [22]. Insurance is not seen anymore as a loss, but as an interesting investment. This is linked to the literature on insurance fraud. Tennyson (2002) find a correlation between the insured's experience with insurance and the level of fraud: people who have several insurance policy and/or who experienced recent claims are less tempted to fraud on insurance. There is then a need for insurance education in order to raise public awareness. If people increase their level of knowledge of the insurance system and its procedure and functioning, they will better understand the benefits of insurance, which will reduce fraud and under-insurance.

2.6 Conclusion

Of particular interest here is whether the insurance decision is fundamentally different for precise, imprecise and controversial extreme events, and whether it is possible to find some determinants of insurance demand through a survey administered to a large representative sample of the French population. Our results provide the evidence of the behaviors of non-sophisticated subjects on the insurance market. Two decisions are differentiated: the insurance decision per se and the willingness to pay. On the one hand, almost one third of the population is not ready to take insurance and that decision is impacted by the socio-demographic characteristics of the respondents and by the degree of trust they have in the insurance industry. On the other hand, the individuals asking for insurance exhibit risk aversion and ambiguity seeking behaviors. In situations of risk, individuals feel

22. They also find that large claims lead to shorter policy tenure and gambler's fallacy, the fact that individual experience a major flood and think they will not experience that kind of loss for many years, so do not renew their policy.

comfortable and trust the experts. In situations of ambiguity, they raise doubts because of the difficulty to assess low probability events or to trust experts that might be wrong. They consider ambiguous situations as inferior and are not willing to pay so much for them. Furthermore they exhibit conflict aversion and always prefer a consensual information in which the information is unknowable. They dislike controversial situations because they feel insecure in trusting one expert over the other. Then, the risk characteristics, the information type, the context, the beliefs and the personal characteristics affect the decision-making process of insurance demand.

On the demand side, respondents exhibit risk aversion, they are willing to pay a higher premium than the expected loss, but the premium they are willing to pay decreases in situations of ambiguity (imprecision and conflict). However, on the supply side, previous studies have shown that insurers are slightly risk averse but strongly increase the premiums in situations of ambiguity (Cabantous, 2007; Cabantous et al, 2011). In a free market, supply has to meet demand. Therefore, an insurance market for extreme events, where the risk characteristics are precise, can exist, but it seems that there is no possibility for a free market for extreme events where the risk characteristics are ambiguous. In that sense, Einhorn and Hogarth (1986) reveal that sellers of insurance exhibit more ambiguity aversion than buyers of insurance. Indeed, the agent who supports the risk gives more attention to loss amounts because a misunderstanding of the probabilities can lead to severe consequences. Furthermore, the buyer always wants the lowest price and is more ready to trust the lowest estimates. In order to have a market for extreme and ambiguous risks, it is important that insureds and insurers have similar view of the risk characteristics. Therefore, communication on the risks has to be improved. An alternative solution is that of government intervention, through public-private partnerships or by making insurance for extreme risks compulsory.

These results point to a panel of recommendations concerning the communication of insurance companies. The first of them would be for insurers not to communicate in the same manner according to the risks and to the available information. Insurance companies should provide both qualitative and quantitative information. In order to avoid a priori judgements on certain risks and to encourage people to buy insurance, it would be useful to present the risks as being of personal concern to the potential buyers. Indeed, the results show a strong difference in the way in which individuals manage catastrophic and man-made events. People think they can handle their own attitude towards risk. Another recommendation deals with the reputation of insurance companies - an issue that has to be taken seriously. In the comments, respondents wrote that insurers manipulate data. Insurers should thus be very transparent in their communication, and straightforward in what regards premiums. The products should be presented in a realistic way. Consumers tend to prefer an imprecise piece of information when experts openly define it as unknowable. They do not want insurers to lie to them or to overload them with information. Therefore, it is important to recognize that there are uncertainties surrounding extreme risks. Furthermore, the reputation of insurance companies seems to improve once people have actually dealt with insurers. It is then essential to develop and secure the loyalty of the clients. It could hence be interesting to consider the way in which people think of insurers according to whether the insurance claims have been paid or have only been reported without having given right to a refund.

A limitation of this survey could be that the questions asked are abstract; connected to rare events and hypothetical situations. Nevertheless, this survey is part of a global project on decision making. The following chapter reports the analyses of surveys dedicated to insurance professionals (insurers and reinsurers), in order to have a global assessment of the insurance market for extreme and ambiguous event risks. The project will provide insights on behaviors in the insurance markets.

2.7 Appendix

2.7.1 Detail of the insurance demand survey

Short instructions before starting:

First of all thank you for participating to this survey dealing with understanding insurance behaviors. It consists in a scientific study about the decision making process of individuals working in insurance. This research is sponsored by the University Paris 1 Panthéon-Sorbonne and will provide support for a PhD in Economics. Completing this survey will take between 12 and 15 minutes depending on your answers. The objective is to analyze how individuals make decisions in situations of risk that may be encountered in professional life. You should consider the hypothetical situations as real life situations. Some situations presented may seem extreme or unrealistic. What is interesting is your decision given the situation. There is no right or wrong answer. This survey is completely anonymous. The survey results will be published in a consolidated form only. If you wish to receive them once it is completed, you can leave your email address. Please read the instructions carefully and answer as honestly as possible. Thank you in advance for your participation.

Functioning of insurance: The policyholder transfers a risk (random by definition) to the insurance company. The insurance company accepts the risk in exchange for an insurance premium. The policyholder is then protected against covered events that he/she does not want to support solely. The insurance mechanism does not modify the occurrence probability of the risk and its consequences. The insurance company realizes a risk mutualization between the insureds through the underwriting of numerous similar risks. This risk management allows the insurer to pay off all the disasters which the insureds will undergo using the premiums paid upfront.

Your role: You are the Head of Risk Management in a large company which owns several buildings. You are in charge of defining insurance contracts that you are willing to buy in order to protect the company against some particular risks. In other words, you choose the insurance coverage against losses linked to potential risks. The purpose is here to analyze the risks of the different buildings in order to cover them separately. Two types of risks can exist: A windstorm risk and an environmental liability risk.

Two risk characteristics:

- The total loss amount : In case of a windstorm risk, it includes direct insured losses (destruction of buildings, contents) and business interruption following the disaster, estimated from the turnover of the company, net deductibles. In case of an environmental liability risk, the total losses amount includes the material and immaterial damages caused to third parties and the clean-up costs.
- The annual occurrence probability of a risk: X% (i.e. 1 every Y years in average).

Experts' opinion: In order to have a accurate vision of the risk, you have engaged two experts. Based on the company business and modeling software, they estimate the annual occurrence probability of the risk (windstorm or environmental liability). The assessment of the loss amount does not cause any trouble to the experts. Three possible cases:

- The experts are in agreement, they have a precise idea of the risk and give a unique probability.
- The experts are in agreement, but they face difficulties in estimating precisely the risk and give an inaccurate estimate of the probability.
- The experts disagree on the estimate, and each expert gives their own probability.

Your mission: For each outlined situation, as Head of Risk Management in a large company, you will have to determine the maximum amount of the insurance premium that you are willing to pay in order to cover a risk entirely. The insurance will guarantee you an integral reimbursement in case of a risk. However, you will always have the possibility of refusing to take insurance. In that case, your company will bear the entire loss in case of a risk occurrence. After each answer, you may write a comment. For example, you can explain how you have settled the premium amount, why you have refused to cover the risk, or under which conditions you would change your mind.

Two risk scenario (in random order):

Windstorm risk scenario:

In this list of 5 questions, your company is looking for insuring against the windstorm risk. Your company owns several buildings spread in different areas. The risk intensity can vary depending on the vulnerability, the exposure, the safety measures, etc.

1. ***Question under risk:*** Your experts agree on a unique probability. They estimate that the occurrence probability of a windstorm is 1.25% (i.e. 1 event every 80 years). The total loss amount for the event would be 100,000€.
2. ***Question under imprecision:*** Your experts agree on an interval for the probability. They estimate that the occurrence probability of a windstorm is between 0.5% (i.e. 1 event every 200 years) and 2% (i.e. 1 event every 50 years). The total loss amount for the event would be 100,000€.
3. ***Question under growing imprecision:*** Your experts agree on an interval for the probability. They estimate that the occurrence probability of a windstorm is between 0.1% (i.e. 1 event every 1,000 years) and 2.4% (i.e. 1 event every 42 years). The total loss amount for the event would be 100,000€.
4. ***Question under conflict:*** Your experts disagree on the probability and they provide two different estimations of the probability. One expert estimates that the occurrence probability of a windstorm is 0.5% (i.e. 1 event every 200 years), the other expert estimates that it is 2% (i.e. 1 event every 50 years). The total loss amount for the event would be 100,000€.
5. ***Question under growing conflict:*** Your experts disagree on the probability and they provide two different estimates of the probability. One expert estimates that the occurrence probability of a windstorm is 0.1% (i.e. 1 event every 1,000 years), the other expert estimates that it is 2.4% (i.e. 1 event every 42 years). The total loss amount for the event would be 100,000€.

For each of the 5 questions (displayed in random order):

What is the maximum insurance premium that you are willing to pay in order to protect yourself against this risk during one year (write 0€ if you refuse to take insurance)? Do you have any comments?

Environmental liability risk scenario:

In this list of five questions, your company uses toxic chemical products in the production process and is looking for insurance against the environmental liability risk. Your company owns several buildings and respects the legal norms concerning dangerous product use. However, there is a risk that a leak breaks out and toxic products pollute the neighbourhood soil.

The same five questions as in the windstorm risk scenario, but with a total loss amount of 2 billion€.

Individual characteristics and other questions:

Socio-demographic questions: sex, birth date, region of living, marital status, number of children, socio-economic group, income level.

Insurance questions:

- Did you report a claim to your insurance company during the last 3 years?
- What was the type of risk?
- What was the approximate cost of the claim?

Extreme event questions:

- Have you, or one of your relatives or friends, suffered losses due to a windstorm?
- Do you think it has changed your perception on windstorm insurance?
- Have you, or one of your relatives or friends, suffered losses due to an environmental pollution caused by a company?
- Do you think it has changed your perception on environmental liability insurance?
- How high do you consider the risk of terrorism is in your country?

Suggestions: Do you have suggestions or comments about this survey? If you want to receive the survey results, please indicate your email address.

2.7.2 Analysis results

Table 2.5: Stata 11 outputs of some Student tests of Table 2.4

One-sample t test on the risk question of the catastrophe scenario						
Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Rcat	1095	1.536206	.151075	4.999189	1.239777	1.832635
mean = mean(Rcat)				t = 3.5493		
Ho: mean = 1				degrees of freedom = 1094		
Ha: mean < 1		Ha: mean != 1			Ha: mean > 1	
Pr(T < t) = 0.9998		Pr(|T| > |t|) = 0.0004			Pr(T > t) = 0.0002	

Paired t test on the I2 and C2 questions of the environmental pollution scenario						
Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
I2env	1002	.6353004	.107113	3.390597	.4251085	.8454922
C2env	1002	.5531648	.0967423	3.062318	.3633238	.7430058
diff	1002	.0821356	.0391592	1.23956	.0052921	.1589791
mean(diff) = mean(I2env - C2env)				t = 2.0975		
Ho: mean(diff) = 0				degrees of freedom = 1001		
Ha: mean(diff) < 0		Ha: mean(diff) != 0			Ha: mean(diff) > 0	
Pr(T < t) = 0.9819		Pr(|T| > |t|) = 0.0362			Pr(T > t) = 0.0181	

Table 2.6: The effects of socio-demographic characteristics on the insurance decision in the windstorm scenario: Probit estimates of the question under risk

	Coefficient	*t-stat*	$P > \|t\|$	*Marginal probability*
Gender (F → M)	-0.025	-0.30	0,767	-0.69%
Age (<25 years old)				
25-49 years old	0.231*	1.77	0.076	7.05%
>50 years old	0.317**	2.12	0.034	9.40%
Socio-economic group (Low)				
High	0.069	0.71	0.475	1.95%
Degree (No education)				
A-level	0.075	0.66	0.509	2.24%
Bachelor degree	0.168	1.52	0.130	4.88%
Master degree or Ph.D.	0.298**	2.06	0.040	8.25%
Income level (Low: <1600€)				
Medium: 1600€- 7600€	0.107	1.05	0.296	3.09%
High: >7600€	0.174	0.98	0.328	4.91%
Marital status (Bachelor)				
Common life	0.014	0.11	0.911	0.40%
Married	-0.044	-0.34	0.731	-1.27%
Separated or divorced	0.196	1.11	0.269	5.12%
Number of children (0)				
1	0.039	0.32	0.748	1.05%
2 and more	-0.088	-0.82	0.412	-2.50%
Region of France (South-West)				
South-East	0.222	1.59	0.113	6.69%
Ile de France (region of Paris)	0.143	0.96	0.338	4.42%
North-West	0.290**	2.06	0.040	8.53%
North-East	0.256*	1.81	0.070	7.61%
Insurance claim	0.266***	2.72	0.006	7.50%
Experience in windstorm risk	0.271***	2.63	0.009	7.62%
Experience in environmental risk	-0.237	-1.07	0.284	-6.67%
Perception of the level of terrorism	0.151*	1.88	0.060	4.25%
Constant	-0.516	-1.48	0.139	
Pseudo R^2	0.038			

*** p<0.01 ; ** p<0.05 ; * p<0.1

Note: Marginal probabilities refer to the probability of buying insurance. It gives the predicted probability at each level of the observable characteristics, holding all other variables in the model at their means.

Table 2.7: The effects of socio-demographic characteristics on the insurance decision: Probit estimates with fixed effects

	Coefficient	*SD*	*t-stat*	$P > \|t\|$	*Marginal probability*
Gender (F vs M)	-0,056**	0,025	-2,250	0,024	-1,63%
Age (<25 years old)					
25-34 years old	0,223***	0,044	5,030	0,000	6,48%
35-49 years old	0,160***	0,046	3,490	0,000	4,55%
50-59 years old	0,083*	0,049	1,690	0,092	2,30%
60-65 years old	0,038	0,059	0,650	0,519	1,03%
Socio-economic group (Low)					
High	-0,002	0,031	-0,070	0,945	-0,06%
Without activity (retired, student)	0,139***	0,033	4,200	0,000	4,14%
Degree (No education)					
A-level	0,233***	0,036	6,520	0,000	6,38%
Bachelor degree	0,295***	0,035	8,470	0,000	8,24%
Master degree or Ph.D.	0,380***	0,043	8,900	0,000	10,94%
Marital status (Bachelor)					
Common life	0,133***	0,050	2,680	0,007	4,17%
Married	-0,141***	0,038	-3,670	0,000	-4,06%
Separated or divorced	0,008	0,037	0,210	0,837	0,23%
Number of children (0)					
1	-0,024	0,036	-0,670	0,505	-0,71%
2 and more	-0,084**	0,033	-2,550	0,011	-2,45%
Income level (<1600€)					
1601-3000€	0,077**	0,034	2,300	0,021	2,24%
3001-7600€	0,156***	0,041	3,860	0,000	4,64%
>7600€	0,228**	0,093	2,460	0,014	6,91%
Refusal to respond	-0,201***	0,048	-4,220	0,000	-5,28%
Region of France (South-West)					
Ile de France (Region of Paris)	0,048	0,045	1,070	0,286	1,39%
North-East	0,035	0,043	0,820	0,410	1,03%
North-West	0,040	0,043	0,950	0,345	1,18%
South-East	0,010	0,043	0,230	0,820	0,28%
Experience in windstorm risk	0,093***	0,028	3,270	0,001	2,71%
Experience in environmental risk	-0,053	0,065	-0,830	0,408	-1,56%
Insurance claim	0,184***	0,027	6,910	0,000	5,40%
Perception of the level of terrorism	0,111***	0,024	4,630	0,000	3,26%
Type of risk (Windstorm vs Environmental)	-0,637***	0,024	-26,920	0,000	-18,65%
Type of information (Risk)					
Imprecision	-0,066**	0,032	-2,080	0,037	-1,96%
Conflict	-0,103***	0,032	-3,270	0,001	-3,06%
Constant	-0,456***	0,096	-4,730	0,000	
Pseudo R^2	0,071				

*** p<0.01 ; ** p<0.05 ; * p<0.1

Table 2.8: The effects of socio-demographic characteristics on the willingness to pay for insurance regression

	Coefficient	*SD*	*t-stat*	$P > \|t\|$
Gender (F vs M)	-0,150	0,204	-0,730	0,463
Age (<25 years old)				
25-34 years old	-0,913*	0,527	-1,730	0,083
35-49 years old	-1,832***	0,503	-3,640	0,000
50-59 years old	-1,846***	0,521	-3,540	0,000
60-65 years old	-1,484**	0,631	-2,350	0,019
Socio-economic group (Low)				
High	-0,680**	0,305	-2,230	0,026
Without activity (retired, student)	-0,130	0,267	-0,490	0,627
Degree (No education)				
A-level	-0,495	0,344	-1,440	0,150
Bachelor degree	-0,625*	0,320	-1,950	0,051
Master degree or Ph.D.	-0,822*	0,469	-1,750	0,080
Marital status (Bachelor)				
Common life	-0,917**	0,419	-2,190	0,029
Married	-0,936**	0,370	-2,530	0,012
Separated or divorced	-0,425	0,384	-1,110	0,268
Number of children (0)				
1	0,299	0,345	0,860	0,387
2 and more	-0,902***	0,276	-3,270	0,001
Income level (<1600€)				
1601-3000€	-0,899***	0,321	-2,800	0,005
3001-7600€	-0,541	0,416	-1,300	0,193
>7600€	-1,025**	0,500	-2,050	0,041
Refusal to respond	-0,695	0,540	-1,290	0,198
Region of France (South-West)				
Ile de France (Region of Paris)	0,292	0,367	0,800	0,427
North-East	-0,226	0,350	-0,640	0,519
North-West	0,394	0,404	0,980	0,329
South-East	-0,378	0,346	-1,090	0,275
Experience in windstorm risk	0,248***	0,271	0,910	0,001
Experience in environmental risk	-1,068	0,313	-3,410	0,360
Insurance claim	0,362	0,248	1,460	0,144
Perception of the level of terrorism	1,177***	0,219	5,370	0,000
Type of risk (Windstorm vs Environmental)	-0,358	0,228	-1,570	0,116
Type of information (Risk)				
Imprecision	-0,094	0,282	-0,330	0,740
Conflict	-0,134	0,288	-0,460	0,642
Constant	5,170***	0,869	5,950	0,000
R^2	0,057			

*** p<0.01 ; ** p<0.05 ; * p<0.1

CHAPTER 3

Insurance professionals under imprecision and conflict for extreme risks: How does information affect the premium?

3.1 Introduction

Correctly assessing the risk characteristics of adverse events, i.e. the potential losses and the associated occurrence probability, is essential to the insurability of a risk, allowing the use of actuarial methods for pricing insurance contracts. However, extreme risks do not necessarily verify this condition, due to non-availability of historical records, changing environments or new regulations. Insurance professionals use modeling tools to estimate the magnitude of the occurrence probability, tools that can give imprecise or controversial estimates, creating attitudes toward ambiguity that are transferred into the insurance and reinsurance premiums. Furthermore, with the new European solvency regulation that the insurance industry has to comply with, insurers are forced to enhance risk assessment and risk management. In this context, it is interesting to understand the attitudes of professionals facing extreme events, and the role of ambiguity in the insurance risk transfer mechanism.

In an insurance environment with no historical data available, insurance professionals compensate the difficulty of having an accurate prediction of future claims by using several modeling tools in order to quantify the risks. These tools - being external experts - are representations of the reality and can give imprecise or conflicting estimates of the occurrence probabilities. Insurance professionals do not use the same methods according to the risks, they do not manage in the same way a thievery, a windstorm and a pollution risk. "Normal" risks are repetitive relatively small risks that can be estimated from historical data. There are called "attritional" risks in the insurance jargon. Extreme risks such as catastrophe risks are much delicate to model, and insurers usually use modeling tools [1] that run stochastic methods to come up with an occurrence probability. These methods need hypotheses, for example on the exposure and vulnerability of the buildings, which are not necessarily satisfied and create imprecise information. Furthermore, insurers usually work with more than one model in order to be more exhaustive and enlarge their knowledge, which create conflicting situations when the model outputs are different. Regarding unusual risks such as an environmental pollution, insurers also face conflict as they work with

1. Three main commercial models exist on the market for modeling natural catastrophes: AIR Worldwide, EqeCat, and Risk Management Solutions (RMS) tools.

several scenarios. Therefore, in their day-to-day practices, insurers often need to aggregate several pieces of information in order to take their decisions.

Risk management is at the heart of the insurance profession, and correctly assessing the risks allows the result stability of the insurance company, as risk coverage assessment is used for the premium calculation, the reinsurance protection, and the economic capital assessment. A correct assessment is even more important with the European Solvency II Directive that institutes more transparency, documentation and justification in the risk estimation. This context is highlighting the willingness of insurers to understand the risks and to collect more information in order to be more exhaustive and objective, which does not necessarily decrease the ambiguity level. Insurance professionals are a very particular population with a specific expertise in assessing risks. As Smith and Sultz (1985) says, managers can only use that expertise if they have some discretion in the choice of their actions, so their decisions are also based on their own risk aversion [2]. Froot (2011) also puts in perspective the risk aversion of insurers in the insurance company because risk averse behaviors explain the transfer from insurers to reinsurers in order to decrease the exposure concentration. In the case of extreme events, the problem is that no one knows which probability is the true one and which model to trust. Then, the risk perception of insurance professionals influences even more their risk assessment. Ambiguity averse behaviors may lead insurers and reinsurers to set higher premiums (Froot, 2001). Then, insurance professionals could be more accustomed to behave under imprecision and conflict than the common people, and could exhibit different attitudes toward risk and ambiguity than the common population.

Insurance decisions are not always taken in a risky environment where it is possible to define precise probabilities for the events, but in an uncertain environment where the information is not complete, namely an ambiguous situation. Different ambiguity sources can be distinguished. Imprecision refers to a situation in which the information is consensual but imprecise; and conflict refers to a situation of disagreement between experts. Smithson

2. Smith and Sultz (1985) suppose a contract between the manager and the company which includes incentives to increase the value of the firm while the manager increase their expected utility.

(1999) defines conflict aversion as the fact that individuals prefer a consensual information over a controversial one. He explains that conflicts are perceived as less credible and trustworthy. The literature on decision making on insurance of extreme events brings to light that insurance professionals behave differently in the presence of risk (Kunreuther et al, 1995), imprecision (Hogarth and Kunreuther, 1992) and conflict (Cabantous, 2007). In addition, they face difficulties in interpreting small probabilities and do not only reason based on the expected value. These papers cannot compare insurance behaviors on the same basis. Insurance decisions are not yet entirely understood and it is interesting to analyze them through a survey on the professionals of the sector, in line with the analysis of insurance demand shown in the previous chapter. Considering the effects of ambiguity on insurance decisions dealing with extreme event risks is an important step in the conception of insurance and prevention strategies dealing with these risks.

Our analysis of insurance professionals allows to compare decisions for both sides of the markets for both insurance and reinsurance markets. How do (re)insurance decisions for ambiguous risks stand in comparison to decisions for well-known risks? How do insurance professionals perceive imprecise and conflicting situations? Are they like ordinary insureds? If the (re)insurers only accept a very high premium for extreme risks under ambiguity, is there a demand for coverage for these same risks? Agents on the demand and the supply sides might not be as ambiguity averse. How do insurance professionals reason in comparison to non-sophisticated respondents?

This chapter reports a survey administered to insurance professionals. They were asked to give their premiums to purchase or sell an (re)insurance contract against a specific low-probability risk. The different types of information are introduced according to expert's estimates regarding the occurrence probability. Under risk (R), the experts agree that the probability is well-known and precise. Under imprecision (I), they agree that it takes a range of possible values, but they cannot narrow down the estimation. Under conflict (C), they disagree and each has its own precise estimate. The respondents can face two adverse events (natural or man-made catastrophes) and respond to two questionnaires among four (insurance demand, insurance supply, reinsurance demand, reinsurance supply) according to their position on the market. The idea behind the insurance demand questionnaire is to check the attitudes in their non-professional life. Respondents had to give their willingness to pay (WTP) on the demand sides and their willingness to accept (WTA) on the supply sides for (re)insurance contracts covering low-probability events and under a specific information type (R, I or C). Respondents had the choice between setting the premium and refusing to buy/sell insurance. In addition, they had to tell how easily it would be for them to justify their choice.

Our results provide the evidence that insurance professionals are a sophisticated population that behaves differently from the "normal" respondents, as they answered questions in relation with their day-to-day practice. However, they also face difficulties assessing ambiguous situations. Insurance professionals exhibit risk, ambiguity and conflict aversions, and they refuse more (re)insurance (both subscribing and underwriting) under ambiguity than under risk. In addition, the demand premiums are lower than the supply ones on the insurance market, while they are higher than the last ones on the reinsurance market. Agents seem more ambiguity averse on the insurance market, and more risk averse on the reinsurance market, a market with a greater expertise in the transfer of extreme risks. Moreover, the higher the premium and the ambiguity, the more difficult is the justification. The rational processes are different under risk and ambiguity, on demand and supply. Reasoned choices are harder to make under ambiguity due to the lack of objective information.

The chapter is structured as follows. The second section presents some theoretical background on insurance decisions under ambiguity on the demand and supply side of the market. The third section introduces the predictions and the design of the survey. The fourth section presents the survey results, regarding the attitudes to information types, the demand and supply premiums, the effect of justification and the explanatory factors. In concluding, the chapter discusses the results and raises questions for further research.

3.2 Some theoretical background on insurance under risk and ambiguity

3.2.1 Setting the scene

The expected utility model (EU) of von Neumann et Morgenstern (1947) is the reference model for preference representation. The subjective expected utility (SEU) model proposed by Savage (1954) allows to model a decision under ambiguity as a decision under risk, with a subjective probability distribution replacing the objective one. By this way, it does not distinguish objective and subjective information, and it assumes that each decision maker knows precisely the probability distribution. However, the axioms are not always verified (see Ellsberg, 1963, for the main counter example; and Gilboa et al, 2012, for a general review of the axioms' inadequacy). In particular, the SEU model is not able to separate risk and ambiguity attitudes, and several models have been proposed since in order to represent the preferences according to the available information.

In this part, we give some basic results on the willingness to pay and to accept for full coverage under risk and ambiguity in a simple, two-states of nature insurance problem: $S = \{L; \overline{L}\}$ is the state space with $L = \{Loss\}$ and $\overline{L} = \{No\ loss\}$; and $\mathscr{X}$ is the outcome space. A decision is a couple $(a; b)$ where a is the outcome if a loss occurs and b if no loss occurs. The decision maker evaluates decisions based on their preferences and beliefs of the risk characteristics. Let V be the value attached to these decisions. Then, the decision maker will prefer a decision over another by comparing both decisions' values.

Consider an individual with an initial wealth w who faces a risk of loss l. He wonders about buying or not an insurance contract. In a stylized model with either full insurance or no insurance at all, he can make two main decisions:

- The individual can decide not to buy insurance : $f_d = (w - l; w)$, and the outcome depends on the probability distribution of loss between the two states.
- The individual can decide to buy full insurance at a premium π : $g_d = (w - \pi; w - \pi)$, and the outcome is not impacted by the states of nature.

Consider now an insurer with an initial capital k, wondering about selling or not insurance contract to an individual. In a two-player problem, he can make two decisions:

- The insurer can decide not to sell insurance : $g_s = (k; k)$, and the outcome is not impacted by the states of nature.
- The insurer can decide to sell full insurance at a premium π : $f_s = (k + \pi - l; k + \pi)$, and the outcome depends on the loss probability distribution between both states.

The individual will purchase insurance if $V(g_d) > V(f_d)$, and the insurer will sell insurance if $V(g_s) < V(f_s)$. The maximum premium the individual is willing to pay and the minimum premium the insurer is willing to accept for insurance are the solution to $V(g_i) = V(f_i)$, with $i = \{d; s\}$. In order to compare $V(f)$ and $V(g)$ according to the available information, we will contemplate different functional forms for V (see Chapter 2). For all of them g entail no exposure to any uncertainty, and will be evaluated by $V(g_d) = u(w - \pi)$ and $V(g_s) = u(k)$ where $u : \mathscr{X} \longrightarrow \mathbb{R}$ is a monotonic, increasing and concave utility function over outcomes, reflecting risk aversion. On the supply side, u can take into account a contract between the insurer and the firm with incentives to increase the firm's value while increasing her utility (Smith and Sultz, 1985).

3.2.2 Insurance decisions for well-estimated risk

In situations of precise risk, the decision maker has enough information to precisely estimate the probability distribution $(p\,; 1 - p)$, where p is the probability of state L and $(1 - p)$ the probability of state $\overline{L}$. With EU preferences, the value of decision f_d of the individual is:

$$V_{EU}(f_d) = pu(w - l) + (1 - p)u(w)$$

The willingness to pay π for full coverage is the solution of $u(w - \pi) = V_{EU}(f_d)$, and from Jensen's inequality, we get $\pi_{EU} > pl$. Then, a risk averse individual will pay a premium strictly higher than the expected loss (pl). Furthermore, with EU preferences, the value of decision f_d of the insurer is:

$$V_{EU}(f_s) = pu(k + \pi - l) + (1 - p)u(k + \pi)$$

The willingness to accept π_{EU} for full coverage under the Expected Utility framework, is also $\pi_{EU} > pl$, with no other constraint.

On the market, insurers choose the insurance premiums. A premium calculation is always based on the exchange value of future and random financial flows. Most estimation methods are based on the hypothesis that the risks are known, for example from historical data. The basic pricing of insurance contracts is based on law of large numbers ensuring that when aggregating a sufficiently large number of independent and identically distributed risks, the insured loss will tend towards the average loss. This result is the basis for the determination of the pure premium to be equal to the expected loss. Thus, if the probability of theft of a given car is 0.01, an insurance company that insures 10,000 vehicles may be expected to pay a number of claims equal, on average, to 100 stolen cars.

From a statistical point of view, suppose an independent and identically distributed (i.i.d.) random variable X_i, for $i = 1, ..., n$, representing the possible losses for n different insureds. We have $E(X_i) = E(X_1) \forall i = 1, ..., n$ and $E(X_i) < +\infty$. In our two-states insurance problem, $X_i \in \{0; l\}$ with $P(X_i = l) = p$ and $E(X_i) = E(X_1) = pl$. According to the law of large numbers, we have:

$$P\left(\underset{n \to +\infty}{Lim} \frac{1}{n} \sum_{i=1}^{n} X_i = E(X_1) \right) = 1$$

$$\Rightarrow \underset{n \to +\infty}{Lim} \frac{1}{n} \sum_{i=1}^{n} X_i \overset{a.s.}{=} pl$$

Then, for n large enough:

$$\forall \varepsilon, \ \frac{1}{n} \sum_{i=1}^{n} X_i \in [E(X_1) - \varepsilon; E(X_1) + \varepsilon]$$

This is what justified the fact that the insurance premium is at least equal to the actuarial premium pl on the supply side. If the premium is equal to the expected loss ($\pi = pl$), the insurer is supposed to be risk neutral ($u(x) = x$). However, insurers usually take into account a safety margin, in percentage of the expected loss, proportional to the risk level: $\pi = (1 + b)pl$, with $b > 0$. The safety margin could also be a percentage of the variance or standard deviation. On the supply side, the decisions to subscribe insurance contracts depend on much more factors such as taxes, cost of financial distress and risk aversion (Smith and Sultz, 1985), as insurers insure several risks and individuals, and want to mutualize the risks across them.

3.2.3 Insurance decisions facing ambiguous events

In situations of ambiguous risk, the decision maker has an imprecise knowledge of the probability distribution. The information is defined as a set P of probability distributions in which lies the true probability. In our insurance problem, $P = \{(p; 1-p)|p \in [p_{min}; p_{max}]\}$, the decision maker only knows that the probability of loss ranges between p_{min} and p_{max}. The actuarial expected probability is equal to $p = \frac{1}{2}(p_{min} + p_{max})$. In this way, the decisions under ambiguity can be compared with the decisions under risk.

Several models have been proposed in order to model ambiguous situations. The MaxMin expected utility ($MaxMinEU$) model of Gilboa and Schmeidler (1989) considers that the decision maker evaluates a decision by computing its minimal expected utility on a subjective space state. Then, in our context, the decision maker will only take in to account the worst probability distribution which is the one with the highest loss probability. The decisions f_d and f_s can be evaluated as follows:

$$V_{MaxMinEU}(f_d) = p_{max}u(w - l) + (1 - p_{max})u(w)$$

$$V_{MaxMinEU}(f_s) = p_{max}u(k + \pi - l) + (1 - p_{max})u(k + \pi)$$

In terms of willingness to pay and to accept, and with the same method as previously, we find an insurance premium of $\pi_{MaxMinEU} > p_{max}l$. A risk neutral individual will be willing to pay exactly $p_{max}l$. Then, $V_{EU} > V_{MaxMinEU}$, a risky situation is always preferred to an imprecise one when p is the center of the intervals $[p_{min}; p_{max}]$ or $[p_{min}-\epsilon; p_{max}+\epsilon]$. In case of growing ambiguity, the probability set becomes $P' = \{(p; 1-p) | p \in [p_{min}-\epsilon; p_{max}+\epsilon], \epsilon > 0\}$, and the maximum premium a risk averse individual will be willing to pay will be at least $(p_{max} + \epsilon)l$, as the highest possible loss is growing.

This model is very pessimistic as it only considers the worst case scenario. However, the probability distribution of this model is subjective, and the highest subjective probability can be different from the maximum probability of the given interval. Indeed, the decision maker can judge that the worst case scenario is different from the given one, in worse or in better.

The alpha MaxMin expected utility model ($\alpha MaxMinEU$) of Ghirardato et al (2004) allows to generalize the $MaxMinEU$ model in taking into account both the minimal and the maximal expected utility. With $\alpha MaxMin$ preferences, the decision f_d of insurance demand becomes $V_{\alpha MaxMinEU}(f_d) = \alpha[p_{max}u(w-l)+(1-p_{max})u(w)]+(1-\alpha)[p_{min}u(w-l)+(1-p_{min})u(w)]$; and the decision f_s of insurance supply $V_{\alpha MaxMinEU}(f_s) = \alpha[p_{max}u(k+\pi-l)+(1-p_{max})u(k+\pi)]+(1-\alpha)[p_{min}u(k+\pi-l)+(1-p_{min})u(k+\pi)]$.

This model define α as the attitude towards ambiguity, and appears more balanced compared to the $MaxMinEU$ model. Here, the maximum insurance premium the decision maker is willing to pay and the minimum insurance premium the decision maker is willing to accept are both equal to $\pi_{\alpha MaxMinEU} = [\alpha p_{max} + (1-\alpha)p_{min}]l$. If the decision maker exhibit ambiguity aversion, $\alpha > 0.5$, more weight is given to the worst case scenario. If $\alpha = 1$, we get back to a $MaxMinEU$ representation.

In our insurance context, the information is imprecise but objective, the models based on $MaxMinEU$ representations capture subjective information, i.e. the beliefs of the decision maker on the ambiguity of the probability distribution. It is more appropriate here to use the model of Gajdos et al (2008) [3] that captures objective imprecise information. Gajdos et al (2008) represent preferences in taking a convex combination of the minimum

3. In our special case with only two states of nature, this model is similar to $\alpha MaxMin$ of Ghirardato et al (2004).

expected utility with respect to all P, and the expected utility with respect to a precise p in P. Therefore, the decisions f_d and f_s can be computed as follows:

$$V_{GHTV}(f_d) = \alpha[p_{max}u(w-l) + (1-p_{max})u(w)] + (1-\alpha)[pu(w-l) + (1-p)u(w)]$$

$$V_{GHTV}(f_s) = \alpha[p_{max}u(k+\pi-l)+(1-p_{max})u(k+\pi)]+(1-\alpha)[pu(k+\pi-l)+(1-p)u(k+\pi)]$$

α represents the attitude towards imprecise information, and $p = \frac{1}{2}(p_{min} + p_{max})$ is the actuarial expected loss. In terms of willingness to pay and to accept, we find an insurance premium π of:

$$\pi_{GHTV} > \left(\alpha p_{max} + (1-\alpha)\frac{p_{min} + p_{max}}{2}\right) l$$

If $\alpha > 0$, the decision-maker lends more weight on p_{max}: the premium is higher in an imprecise situation than in a precise one, which denotes ambiguity aversion: $V_{EU} > V_{GHTV}$ and $\pi_{EU} < \pi_{GHTV}$. If $\alpha = 1$, it is an extreme case where the decision maker only takes into account the worst case. If $\alpha = 0$, we get back to an EU representation.

In actuarial terms, insurers tend to increase the safety margin under ambiguity. If they follow the $GHTV$ model, the safety margin is equal to: $b = \alpha\left(\frac{p_{max}-p_{min}}{p_{min}+p_{max}}\right)$. Then, the safety margin increases with the ambiguity aversion α.

In case of growing ambiguity, $P' = \{(p;1-p)|p \in [p_{min} - \epsilon; p_{max} + \epsilon], \epsilon > 0\}$ is the new probability set, and the premiums will be at least $\left(\alpha p_{max} + \alpha\epsilon + (1-\alpha)\frac{p_{min}+p_{max}}{2}\right) l$, which denotes growing ambiguity aversion if $\alpha > 0$. When an ambiguous situation becomes even more ambiguous, i.e. when the probability set enlarges to 2ϵ, the insurance premium increases of $\alpha\epsilon l$.

In presence of ambiguity, insurance professionals face much more difficulties assessing the risks. Especially, for extreme events, they cannot reason based on historical data. If the information on the probability of loss is ambiguous, the results of the law of large numbers are no longer true. Marinacci (1999) and Maccheroni and Marinacci (2005) have developed an equivalent of the law of large numbers for special cases of imprecise probabilistic information, in which the information is characterized by a capacity (and not with a unique probability distribution). They set that, when the probability of loss belongs to an interval $[p_{min}; p_{max}]$, the loss per insureds belongs (with a probability that tends to one when the number of insured tends to infinity) to the interval of the average losses calculated with p_{min} and p_{max}. Thus, any pure premium based on the values of p in the interval $[p_{min}; p_{max}]$ can be justified and this premium will depend on the attitude toward ambiguity of the insurer. Thus, if the probability of theft of a given car lies between 0.01 and 0.03, an insurance company that insures 10,000 vehicles can expect to pay a number of claims between 100 and 300 stolen cars. With a large number of insureds, the estimated probability will not necessarily tend to the true probability, which can be due to heterogeneous characteristics of insureds or to missing information.

From a statistical point of view, if we note a capacity ν such that $\nu(X_i = l) = p_{min}$ and $\nu(X_i = 0) = 1 - p_{max}$, Marinacci (1999) and Maccheroni and Marinacci (2005)'s results show that:

$$P\left(p_{min}l \leqslant \underset{n\to+\infty}{Lim\ inf}\ \frac{1}{n}\sum_{i=1}^{n} X_i \leqslant \underset{n\to+\infty}{Lim\ sup}\ \frac{1}{n}\sum_{i=1}^{n} X_i \leqslant p_{max}l\right) = 1$$

In this case, the law of large numbers does not give a precise limit of $\frac{1}{n}\sum_{i=1}^{n} X_i$, and this limit may not exist. For n large enough, this law gives a superior and an inferior bounds. Then, the actuarial premium could take any values between $p_{min}l$ and $p_{max}l$, which makes this rule difficult to apply in concrete terms.

We can note two possible scenarios:

i. If $\forall i$, $P(X_i = l) = p$, with $p \in [p_{min}; p_{max}]$, then there is a convergence and we have: $\underset{n\to+\infty}{Lim\ inf}\ \frac{1}{n}\sum_{i=1}^{n} X_i = \underset{n\to+\infty}{Lim\ sup}\ \frac{1}{n}\sum_{i=1}^{n} X_i$.

ii. If $\forall i$, $P(X_i = l) = p_i$, with $p_i \in [p_{min}; p_{max}]$, then $\frac{1}{n}\sum_{i=1}^{n} X_i$ do not converge.

3.2.4 Insurance decision under conflict

Conflict occurs when several experts are consulted to estimate the probability distribution, but they disagree and each give their own estimate. Lets consider a decision maker facing conflict from two different experts giving respectively a set of probability distributions P and Q. Gajdos and Vergnaud (2009) represent preferences as follows:

$$\begin{aligned} V_{GV}(f) &= \underset{\gamma\in\Gamma}{Min}\left[\gamma\left(\underset{p\in\phi(P)}{Min}\, E_p u(f)\right) + (1-\gamma)\left(\underset{p\in\phi(Q)}{Min}\, E_p u(f)\right)\right] \\ \text{with} \quad \Gamma &= \left\{(1-\lambda)\left(\tfrac{1}{2};\tfrac{1}{2}\right) + \lambda(t;1-t) \mid t\in[0;1]\right\} \end{aligned}$$

ϕ is a linear mapping representing the subjective treatment of the information, Γ is a symmetric closed and convex subset that represents the attitude toward conflict, and λ ($\lambda \in [0;1]$) can be interpreted as a measure of conflict aversion. This model allows to take into account both attitudes toward imprecision and conflict, and can be read in two steps. First, the decision maker evaluates experts' assessment via ϕ and comes up with a belief for each assessments. Second, the evaluations are aggregated via the set Γ.

In our insurance context with conflict, let consider that one expert says that the loss probability is p_{min}, and the other says it is p_{max}. There is no imprecise information, i.e. P and Q are singletons respectively equal to p_{max} and p_{min}. Following the model of Gajdos and Vergnaud (2009), the value of decisions f_i, with $i = \{s; d\}$, can be written as:

$$V_{GV}(f_i) = \underset{t\in[0;1]}{Min}\left[\left(\frac{1}{2}(1-\lambda)+\lambda t\right) E_P u(f_i) + \left(\frac{1}{2}(1-\lambda)+\lambda(1-t)\right) E_Q u(f_i)\right]$$

$$\begin{aligned} where: \quad E_P u(f_d) =& \quad p_{max}u(w-l) + (1-p_{max})u(w) \\ E_Q u(f_d) =& \quad p_{min}u(w-l) + (1-p_{min})u(w) \\ E_P u(f_s) =& \quad p_{max}u(k+\pi-l) + (1-p_{max})u(k+\pi) \\ E_Q u(f_s) =& \quad p_{max}u(k+\pi-l) + (1-p_{max})u(k+\pi) \end{aligned}$$

In terms of willingness to pay and to accept, we find an insurance premium π of:

$$\pi_{GV} > \left(\lambda p_{max} + (1-\lambda)\frac{p_{min}+p_{max}}{2}\right) l$$

And, in case of growing conflict, the insurance premium increases of $\lambda\epsilon l$, the premium being at least equal to $\left(\lambda p_{max} + \lambda\epsilon + (1-\lambda)\frac{p_{min}+p_{max}}{2}\right) l$. λ captures the attitude toward the experts' disagreement. It reflects an arbitrage between the actuarial expected loss, which gives the same weight to both possible values of p and then do not differentiate the experts; and p_{max}, which allows to differentiate one expert over another.

According to these models of risk, ambiguity and conflict, the decision maker should always prefer a precise situation over an ambiguous one. Furthermore, taking into account the empirical works of Smithson (1999) and Cabantous (2007), the decision maker should always prefer an imprecise situation over a conflicting one, as seen in Chapter 2. Therefore, in our survey, the insurance premiums should be the lowest in presence of risk, and it should increase with imprecision and even more with conflict: $\pi_R > \pi_I > \pi_C$ with $R = \{Risk\}$, $I = \{Imprecision\}$, and $C = \{Conflict\}$. In addition, it is interesting to see how insurance professionals define premium in ambiguous case as the law of large numbers only gives us an interval of possible premiums.

3.3 Predictions and design

3.3.1 Main predictions

The literature on decision making on insurance of extreme events brings to light that insurance professionals behave differently in the presence of risk (R), imprecision (I) and conflict (C) , that they face difficulties in interpreting small probabilities and do not only reason based on the expected value. The structure and questions are based on Kunreuther et al (1993) and Cabantous (2007). We ask questions to insurance professionals in different contexts (catastrophe and man-made events) and market positions (buyers and sellers of insurance or reinsurance). Respondents have to give their WTP or WTA for insurance facing different information types (risk, imprecision and conflict) regarding a specific low-probability risk.

The main goal is to define the insurance market for ambiguous extreme risks and the behaviors of insurance professionals on the demand and supply sides of the markets. Let consider the following couple of hypotheses, based on the previous theoretical literature, and destined to investigate extensions of the empirical literature.

H1. Premiums can be ranked regarding the information types: $\pi_R \leqslant \pi_I \leqslant \pi_C$: Insurance professionals exhibit risk aversion ($\pi \geqslant pl$), ambiguity aversion (π_I and $\pi_C \geqslant \pi_R$), and conflict aversion ($\pi_C \geqslant \pi_I$). They prefer a situation with consensual information over one with controversial information.

H2. The premium payed on the demand side of the (re)insurance market are lower than the premium asked on the supply side of the (re)insurance market ($WTP \leqslant WTA$), and the difference is even stronger with ambiguity.

Furthermore, we test for two other hypotheses, relative to the behaviors of insurance professionals compared to the behaviors of "normal" respondents of Chapter 2. We expect insurance professionals to be more specialized in risk assessment and management than common people.

H3. Insurance professionals exhibit stronger ambiguity and conflict aversions than the non-sophisticated respondents. They are more used to behave under ambiguity, and therefore distinguish more easily the different information types.

H4. Insurance professionals pay more attention to the objective risk characteristics and decide with actuarial measures of risk assessment. They tend to think differently about probabilities than non-sophisticated individuals.

In addition, the hypotheses have to be put in perspective with context (catastrophe or man-made events) and justification effects (the insurance professionals always have to justify their decisions to their manager).

3.3.2 The types of information

During the survey, respondents face the same pattern of information to take their decisions. The respondents have to imagine being a risk manager that calls upon two experts in order to determine the true value of the occurrence probability that an event would cause losses. The information given by the experts can take three forms (see Table 3.1):

- In a risky situation, the occurrence probability can be precisely estimated. The experts come to a consensus and agree on a unique and precise probability : p
- In an imprecise situation, it is impossible for the experts to narrow the occurrence probability to a precise estimate. Therefore, the experts agree that the occurrence probability ranges within an interval : $[p_{min}; p_{max}]$
- In a conflicting situation, the experts might not have the same information or hypotheses. Therefore, they disagree and each expert gives their own estimate of the occurrence probability : either p_{min} or p_{max}

In addition, the survey tests for growing imprecision and conflict situations. In that sense, respondents are requested to respond to two other questions related to two other ambiguous situations. In a growing imprecise situation, the experts agree that the probability range within a larger interval $[p_{min} - \epsilon; p_{max} + \epsilon]$. In a growing conflicting situation, the experts disagree and each expert gives their own estimate: either $p_{min} - \epsilon$ or $p_{max} + \epsilon$.

In order to be able to compare the questions, the precise and consensual estimate of the risky situation (p) is the mean[4] of p_{min} and p_{max}, and of $p_{min} - \epsilon$ and $p_{max} + \epsilon$. We assume that the loss amount estimation is not an issue to the experts (100,000€), hence the expected loss is always the same (1,250€). Ultimately, the respondents answer five questions, which are summarized in Table 3.1. After each question, they have the possibility to write a comment in order to explain their choice. The behaviors under risk and ambiguity can vary depending on the scenario. In addition to the natural risk of windstorm, questions on an environmental liability risk scenario based on de Marcellis (2000) were also asked. This scenario introduces a man-made risk of pollution that could trigger the third-party liability insurance of a company. We used the same probabilities as in the windstorm risk scenario, but with a higher loss amount (2,000,000€), thus the expected value is 25,000€.

4. Contrary to Cabantous et al (2011), we use the arithmetic mean and not the geometric mean. In their paper, they use p equal to 1%, the geometric mean of $p_{min} = 0.5\%$ and $p_{max} = 2\%$.

Table 3.1: Five questions for three different information types

Questions		*Information type*	*Occurrence probability*
R	**Risk**	consensual and precise	1.25%
I1	**Imprecision**	consensual and imprecise	Between 0.5% and 2%
I2	**Growing imprecision**		Between 0.1% and 2.4%
C1	**Conflict**	conflictual and precise	0.5% according to an expert, 2% according to another one
C2	**Growing conflict**		0.1% according to an expert, 2.4% according to another one

3.3.3 The structure of the survey

As presented in Figure 3.1, agents on the selling side of the market have to indicate their minimum willingness to accept (WTA) in order to bear the risks (insurers for the insurance market and reinsurers for the reinsurance market). Agents on the buying side of the market have to indicate their maximum willingness to pay (WTP) in order to transfer the risks (insurers for the reinsurance market). Finally, all agents can answer questions on their WTP for insurance in order to check how insurance professionals behave as insureds. In this sense, we can distinguish four different questionnaires : insurance demand (A), insurance supply (B), reinsurance demand (C), and reinsurance supply (D). The questions in all questionnaires have similar phrasing [5]:

A/C What is the maximum insurance/reinsurance premium that you are willing to pay in order to protect yourself against this risk during one year?(write 0 if you refuse to purchase insurance/reinsurance)

B/D What is the minimum insurance/reinsurance premium that you are willing to accept in order to cover this risk during one year?(write 0 if you refuse to underwrite insurance/reinsurance)

5. See the Chapter 2's Appendix for the details of questionnaire A.

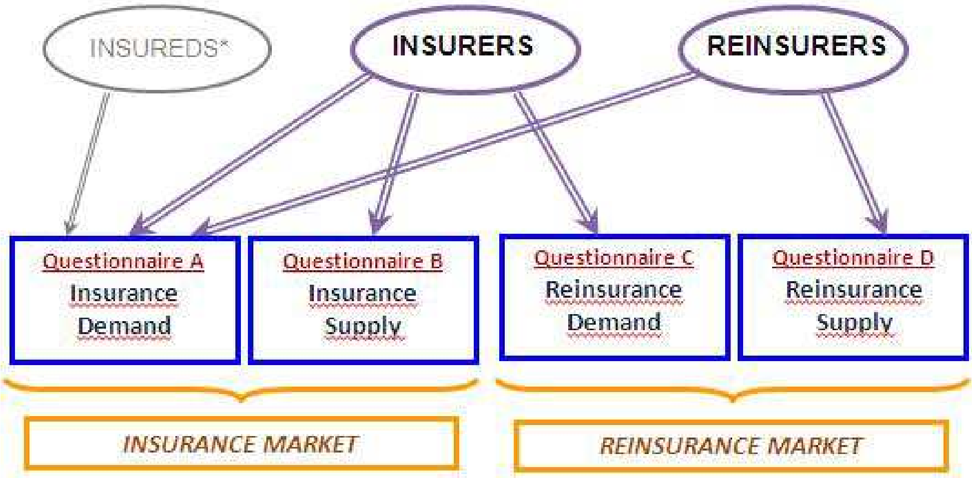

Figure 3.1: Structure of the survey

Note: This figure displays the distribution of the questionnaires across the markets' agents. Insurers could respond to questionnaire A, B or C. They responded to C only if they had knowledge of the reinsurance market. Reinsurers could respond to questionnaire A or D. In grey (*), a previous part of the project was about insurance demand and the results can be found in Chapter 2.

In order to get the precise risk assessment of the insurance professionals on the supply side of the insurance market, the insurers knew they had to give the pure premium they would accept to offer, which is the net premium, i.e. the premium that only corresponds to the risk compensation and does not take into account neither the competition nor the administrative costs. On the reinsurance market, we suppose low competition and administrative costs due to the over-the-counter and oligolistic features of the market. Note that the complete survey can be found in the Appendix.

The questionnaire was divided into three parts. The first two parts were two series of questions from the possible questionnaires. Insurers could respond to questionnaire A, B or C[6]. Reinsurers could respond to questionnaire A or D. For both these parts, there were ten questions about premiums over all. The order of the scenarios and the order of the questions inside each scenario were randomized in order to control for potential order effect. For each question of questionnaire B, C and D, respondents had to tell how easy it would be for them to justify their choices to other, e.g. their manager, on a four-point scale basis[7]. The last part asked about the respondents' characteristics (e.g. gender, age, educational

6. They responded to C only if they had knowledge of reinsurance.
7. A scale ranging from 1 being "very easy", to 4 being "very difficult".

Table 3.2: Distribution of the individuals regarding which questionnaires they responded

Group	Questionnaire				Frequency	Percent
All insurers	A	*Cat*	A	*Made*	18	13,4%
	A	*Cat*	B	*Cat*	22	16,4%
	A	*Made*	B	*Made*	15	11,2%
	B	*Cat*	B	*Made*	13	9,7%
Insurers knowing about reinsurance	A	Cat	C	Cat	8	6,0%
	A	*Made*	C	*Made*	11	8,2%
	B	*Cat*	C	*Cat*	10	7,5%
	B	*Made*	C	*Made*	6	4,5%
	C	*Cat*	C	*Made*	9	6,7%
Reinsurers	A	Cat	D	Cat	9	6,7%
	A	*Made*	D	*Made*	13	9,7%
Total of insurance professionals:					134	100%

Note: The table shows the questionnaire distribution among insurance professionals. A, B, C and D respectively refers to insurance demand, insurance supply, reinsurance demand, and reinsurance supply questionnaires. "Cat" refers to natural catastrophe event, and "Made" to man-made event.

degree, type of insurance job, years of experience, country of working, marital status,...), insurance (insurance claims in the past three years, amount, type), and extreme events (past experience concerning windstorm and pollution risk, perception of the terrorism risk level in their country).

3.3.4 Sampling plan and respondents

The survey was administered to insurance professionals through a web-questionnaire, and lasted around 12 minutes. In this way, the experiment took place in a free environment, and individuals could reveal their beliefs without constraints. The insurers had access to the survey on the intranet website of a big French insurance company. For reinsurers, the survey was send by email to reinsurers being part of the French institute of actuaries. The survey could be taken in French or in English.

Respondents did not receive any incentives, but we presume that insurance professionals know how they would behave in situations where they have the choice, in particular because the questions have a practical orientation through the insurance context. The survey was completely anonymous, thus the respondents did not have any profit to disguise their preferences.

Table 3.3: Summary statistics of the questionnaires across the different information types

		R	**I1**	**I2**	**C1**	**C2**	**Total**
Insurance Demand (A)	*mean*	**1.14**	**1.31**	**1.34**	**1.30**	**1.36**	**1.29**
	sd	0.57	0.80	0.95	0.87	0.99	0.83
	refusals	1%	1%	1%	1%	2%	1%
Insurance Supply (B)	*mean*	**1.29**	**1.56**	**1.76**	**1.66**	**1.69**	**1.58**
	sd	1.08	1.27	1.36	1.23	1.02	1.19
	refusals	5%	5%	11%	9%	22%	10%
Reinsurance Demand (C)	*mean*	**2.36**	**2.98**	**2.99**	**3.20**	**3.34**	**2.96**
	sd	3.87	3.96	4.12	4.08	5.02	4.19
	refusals	9%	13%	13%	13%	21%	14%
Reinsurance Supply (D)	*mean*	**1.39**	**1.40**	**1.65**	**1.53**	**1.70**	**1.53**
	sd	0.64	0.67	0.82	0.76	0.81	0.74
	refusals	18%	18%	18%	23%	23%	20%
Total	*mean*	**1.43**	**1.70**	**1.79**	**1.78**	**1.84**	**1.70**
	sd	1.88	2.00	2.12	2.09	2.42	2.10
	refusals	5%	6%	8%	7%	13%	8%

Table 3.4: Significance of the premiums' differences

	$R - A$	$I1 - C1$	$I2 - C2$	$I1 - I2$	$C1 - C2$
A	$<***$		$<*$	$<***$	$<**$
B	$<***$	$<*$		$<*$	$<*$
C	$<**$	$<*$	$<**$	$<*$	$<*$
D	$<*$	$<*$		$<***$	$<***$
All	$<***$		$<*$	$<**$	$<**$

$*$ if $P \leqslant 0.1$, $**$ if $P \leqslant 0.05$, and $***$ if $P \leqslant 0.01$

Note: Table 3.3 displays the normalized premiums, i.e. the premiums divided by the expected loss (EL), the standard deviations and the percentage of refusals for each questions of the different questionnaires. The premiums do not include the refusals. Table 3.4 displays the results of the Student tests. "A" refers to the ambiguous situations.

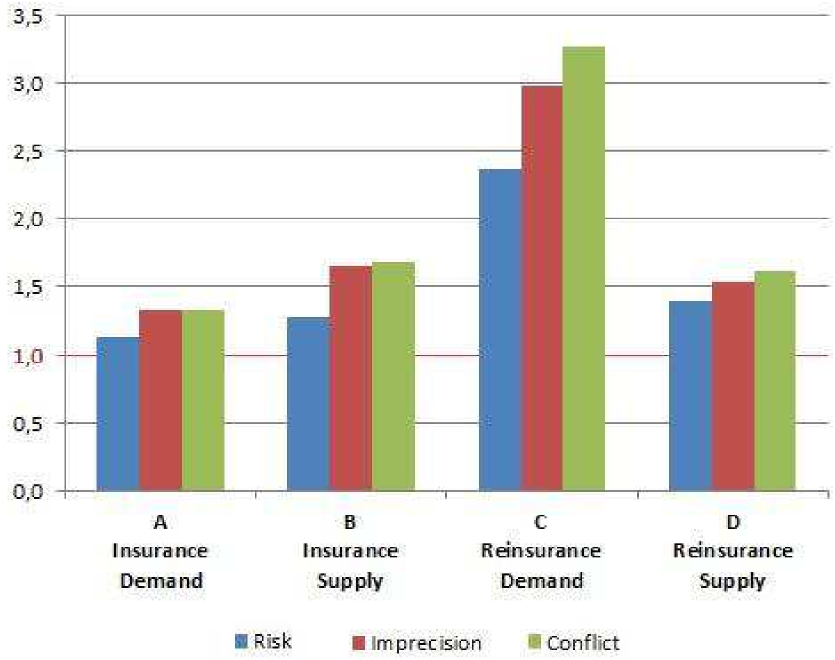

Figure 3.2: Normalized average premiums across the different questionnaires and information types

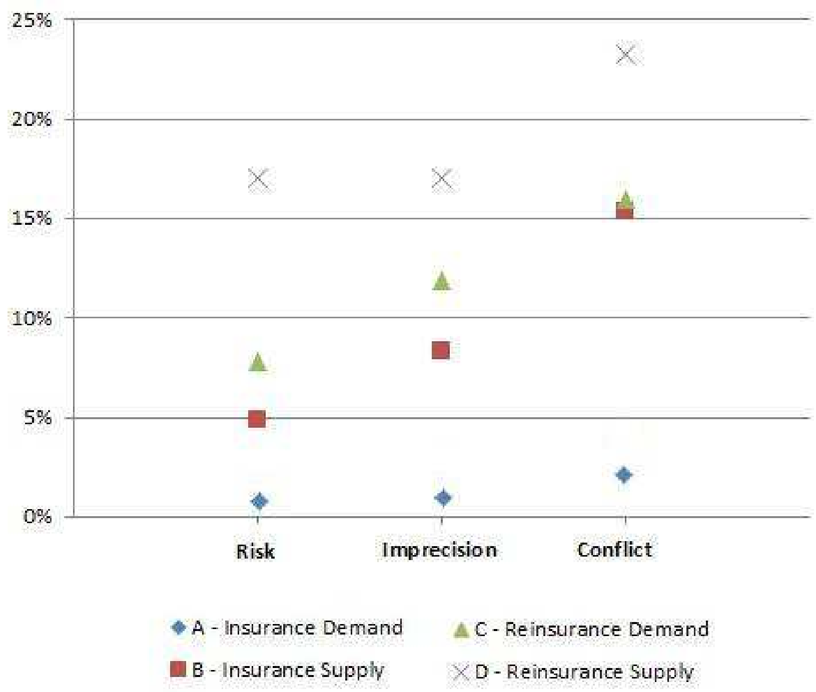

Figure 3.3: Refusals across the different questionnaires and information types (in %)

3.4 Results

3.4.1 Data-set

The final sample consisted of 134 respondents (and therefore 268 questionnaires). Among the respondents, there were 112 insurers and 22 reinsurers. Among the insurers, 42 have responded to the questionnaire C on reinsurance demand. Table 3.2 shows the distribution of the questionnaires within the sample.

It is interesting to note that 35% of the respondents have less than 4 years of experience in insurance, and 36% have more than 10 years. 70% are working in property and casualty insurance, which corresponds to the survey scope. Furthermore, 75% of the respondents have at least a master's degree, including an actuary's degree (which is held by 41% of the sample). Finally, 40% of the sample is older than 35 years old, and there are only 18% of women (see the third column of Table 3.5). Our sample is an interesting mixture of sophisticated respondents, which is coherent with the profiles of individuals working in the insurance industry.

3.4.2 The insurance decisions facing risk, imprecision and conflict

The type of information regarding the estimation of the occurrence probability clearly affects the willingness to pay and to accept of insurance professionals. Table 3.3 and Figure 3.2 report the normalized premiums that insurance professionals are willing to pay and to accept for insuring specific events under three different information types. Table 3.4 displays the significant differences between the information types. A normalized premium of one denotes an insurance premium equal to the expected loss, i.e. a risk neutral attitude. We see that premiums are significantly higher than the expected loss for the five questions. This fact corroborates the hypothesis that decision-maker exhibit risk aversion, in line with Hershey and Schoemaker (1980) for insureds and Kunreuther et al (1995) for insurers.

The results show that insurance decisions vary in presence of ambiguity. The mean premium with precise information is lower than the one with imprecise or conflicting information, meaning that insurance professionals exhibit ambiguity aversion. On the demand side, individuals are willing to pay a larger amount under ambiguity, which is coherent with Hogarth and Kunreuther (1985) for low-probability events. On the supply side, as insurers, they also face difficulties to estimate ambiguous situations, and are willing to accept a higher premium when the probabilities are ambiguous than when they are precise, in line with Hogarth and Kunreuther (1992), Berger et al (1992), and Kunreuther et al (1993).

Regarding the insurance demand questionnaire, we can see that insurance professionals are not like ordinary insureds. The results are very different from Chapter 2, where we had ambiguity seeking behaviors as ambiguous assets are perceived as inferior (Sarin and Weber, 1993). Our insurance professionals exhibit ambiguity averse behaviors, in line with hypothesis H3. They also reason differently, in line with hypothesis H4. In the comments, insurance professionals appear to use actuarial methods to determine their premiums, even for the insurance demand questionnaire. They wrote that they choose the premiums as the pure premium (expected loss) loaded with a charge in percentage of the pure premium. This loading percentage was between 10% and 50%, and always larger under ambiguity in order to add a protection for the unknown information.

In addition, the average premium increase with imprecision and even more with conflict. Insurance professionals also exhibit conflict aversion (even if the differences are not always significant for the four questionnaires). They prefer imprecise over conflicting situations. Furthermore, it increases with growing imprecision and conflict. On average, 36% of the premiums are equal to the expected loss under risk. This percentage falls to 9% under imprecision and 6% under conflict. Then, risk, imprecision and conflict are considered as different situations. Respondents are more willing to pay or accept an actuary fair premium under risk than under ambiguity. These results corroborate hypothesis H1 that insurers are sensitive to the ambiguity source (Cabantous, 2007; Cabantous et al, 2011), i.e. they dislike controversial information and prefer consensual information. On the demand side of the insurance market, the previous Chapter also finds a preference for consensual information and a dislike for conflicts for the general public.

The findings is that the more ambiguous and complex the information, the higher the insurance premiums. The ranking of premiums that we obtain is $\pi_R \leqslant \pi_I \leqslant \pi_C$, in line with H1. Moreover, the amount of money people are willing to pay or to accept increases with the ambiguity level. At an individual level, we find the following results: 79% of the individuals define a premium lower under risk than ambiguity. The ranking between imprecision and conflict is less clear with the following distribution: 40% have a lower premium under imprecision than conflict ($\pi_I \leqslant \pi_C$); 32% define the same value for both situations ($\pi_I = \pi_C$); while 28% define a lower premium under conflict than imprecision ($\pi_I \geqslant \pi_C$). In addition, the percentage of insurance professionals being conflict averse is higher on the reinsurance market than on the insurance market.

People have indicated on average higher premiums for catastrophic events than man-made events, showing a context effect [8]. It goes in line with Cabantous (2007) and Cabantous et al (2011) who found that insurers charge higher premiums for earthquake and hurricane risks than for pollution and fire risks. It might be surprising to underestimate a man-made event like environmental pollution, that represents a long term insurance branch (meaning that the consequences can be spread over a long period of time), and that could be seen as more uncertain than other risks. However, there is a perception bias toward catastrophic event that makes people fear the consequences of natural risks, while they think they know how to manage their man-made risks. Furthermore, the man-made liability risk had a higher possible loss, and as a larger extreme event, it was even more underestimated. Extreme events are more underestimated than common events (Slovic et al, 1977).

Regarding the number of refusals (see Figure 3.3), there are much lower under risk (lower than 2%), than under imprecision (10%), than under conflict (on average 14%). The percentage of respondents not buying or selling (re)insurance increases is even greater in situations of growing ambiguity for both scenarios. Furthermore, refusals are much more important on the supply sides than on the demand sides. Refusals reveal a taste or a deny

8. The Student test of the difference between natural and man-made event reveal a p-value of 0.034.

of the risk on the demand side and a rejection to bear the risk on the supply side. It is surprising for an insurer to refuse to subscribe insurance since he has to give its willingness to accept. Indeed, they could have chosen to accept the risk only at a very high premium, for instance the possible loss minus one euro ($l - 1€$), but they have chosen to refuse. This means that refusing to subscribe is linked to the insurance profession, and not only to the attitudes toward risk and ambiguity. Insurers know that if their price is too high, it will never be accepted by insureds because it is not realistic.

3.4.3 Insurance premiums on the demand and supply sides

Our analysis allows to compare insurance behaviors separating demand and supply decisions under risk and ambiguity. Einhorn and Hogarth (1986) and Hogarth and Kunreuther (1989) distinguish buying and selling situations. They observe that insurance sellers exhibit more ambiguity aversion than insurance buyers, because the agent supporting the risk has to give more attention to the risk characteristics as a misunderstanding can lead to severe consequences. However, the ambiguous information (the type of information) is not defined, they include ambiguity through comments explaining the uncertain situation around a best estimate, which creates a strong anchor effect.

The results of Table 3.3 show that, on the insurance market, the premiums on the supply side are on average 20% higher than the premiums on the demand side, in line with H2. If we look according per information type, we find that the WTA are on average 13% higher than the WTP under risk, 25% under imprecision and 26% under conflict. This means that the gap between the WTP and the WTA is positive and increases with ambiguity. This result is consistent with hypothesis H2. If we look at the individual level, i.e. for a same insurance professional, the WTA are on average 18% greater than the WTP under risk, 75% under imprecision and 60% under conflict. If we consider the gap in the two possible scenarios (risk type), the differences between the WTA and WTP per individual are globally higher in the pollution risk than in the windstorm risk.

If we go back to the theoretical representations previously introduced, it is not possible for a same individual to have different demand and supply premiums with EU or SEU

preferences, as it only depends on p and l, and p is objective here.[9] Under ambiguity, with $MaxMinEU$ preferences, the differences between π_d and π_s can be explained from different subjective beliefs regarding the maximum possible probability (i.e. the worst case scenario). Furthermore, if we suppose $GHTV$ preferences, we can explain that $\pi_{d_{GHTV}} < \pi_{s_{GHTV}}$ with a variation of α depending on the market side: $\alpha_d < \alpha_s$, meaning that the sellers are more ambiguity averse than the buyers. It is similar under conflict if we suppose $\lambda_d < \lambda_s$.

It is also unsure that insurance professionals would be the same WTP as the ordinary individuals. We can then compare the WTA of insurance professionals, that is the insurance premiums they would set for insuring the specific risk of insureds, to the WTP of the ordinary insureds studied in the previous Chapter. We note that, the WTA of insurers are on average 53% higher than the WTP of ordinary insureds. If we look per information type, the WTA are on average 22% higher than the WTP under risk, 66% under imprecision and 72% under conflict. The gap between the demand and supply premiums is larger for man-made events than for catastrophic events. Then, we find similar effect when taking into account demand premiums of insurers and insureds, but with a much larger extent when comparing the two populations. This finding corroborates hypothesis H3 that insurance professionals and non sophisticated respondents do not behave in the same way facing risk and ambiguity. Figure 3.4 shows the distribution of the WTP of the ordinary insureds of Chapter 2, and of the WTP and WTA of the insurance professionals. We can clearly see that the insurance professionals are not like any other insureds.

It seems difficult to reconcile the WTP and the WTA, especially if there is no objective probability. There are several pricing decisions depending on beliefs regarding the probabilities and on the initial endowments (w for insureds and k for insurers). On the demand side, an individual will be more willing to buy insurance at low cost and to consider the minimum probability because, if completely insured, his output in both states will be the

9. However, under risk, it can happen if they have $RDEU$ preferences (Quiggin, 1982). Indeed, they just need to transform differently the probabilities on the demand and on the supply sides, i.e. to have different φ functions according to their position on the market. Then, an individual is willing to pay less than he is willing to accept for a same insurance contract under risk ($\pi_{d_{RDEU}} < \pi_{s_{RDEU}}$) when $\varphi_d(1-p) > \varphi_s(1-p)$. This means that sellers deform more pessimistically the probabilities than buyers.

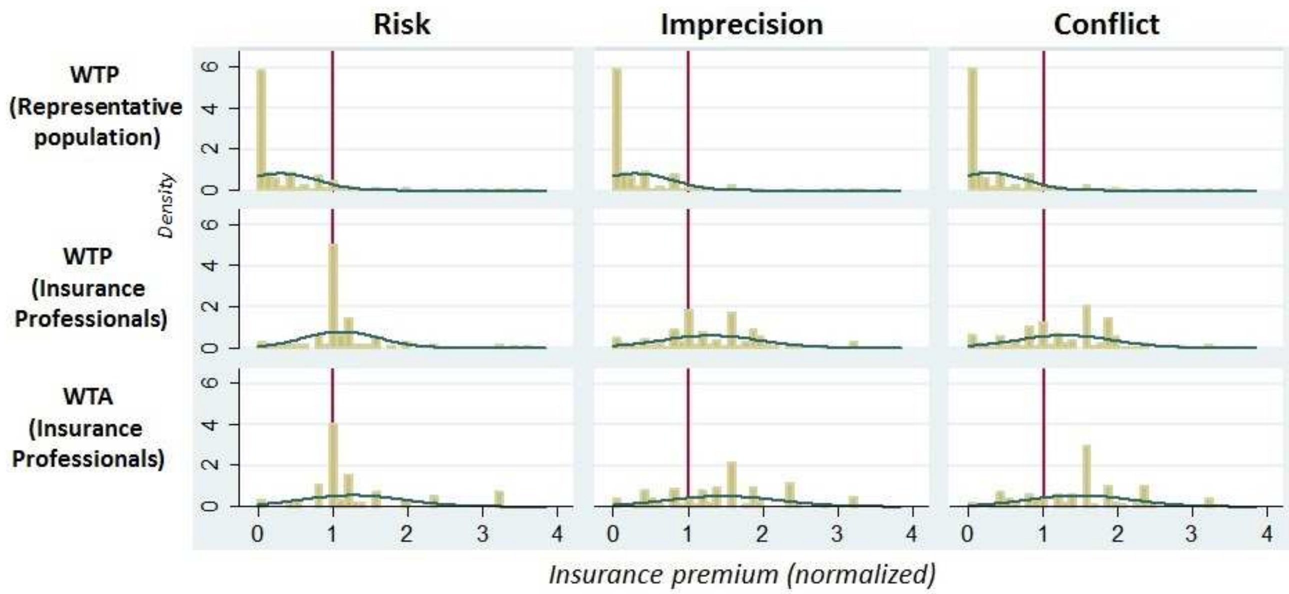

Figure 3.4: Distribution of the WTP and WTA across the types of respondents and information

Note: This figure displays the distribution of the WTP of the ordinary insureds of Chapter 2, and of the WTP and WTA of the insurance professionals. This is a truncated distribution for the ordinary insureds who gave much more dispersed premiums than the insurance professionals.

same. In addition, the insurance premium is often considered as a cost and then, "using" insurance (i.e. claiming on insurance) could be seen as a relatively good state of nature (i.e. a sort of amortization of the insurance policy).

On the supply side, an insurer will be more willing to consider the situation with the worst case scenario, i.e. the maximum loss probability because he needs to pay back the claims in case of losses. As the insurers is supporting the risk, an under-estimation can lead to severe consequences. In addition, we can highlight some supply problems on the insurance market. Firstly, a winner's curse (Mumpower, 1991) can exist under ambiguity. Underwriters can set higher premiums for ambiguous risks than for well-estimated ones in order to avoid underwriting the insurance contract and risking a possible loss. If insurers are uncertain about the experts' estimates of the probability, they would rather price a greater insurance premium in order to avoid winning the contract and experiencing an expected loss that they cannot precisely estimate. It is linked to the costs of collecting information on ambiguous extreme events (Kunreuther et al, 1995), and in particular catastrophic events [10]. Secondly, another explanation of the low subscription of catastrophic insurance can be that insurers fear a lack of capacity of the reinsurance market (Kunreuther, 1984). As extreme risks are generally reinsured, if the reinsurance market is not properly functioning, insurers will refuse to subscribe - or only very high premiums. If regulations allow for public reinsurance or if reinsurance is cheap due to other financial leverage, then extreme events are not usually actuarially fair priced on the insurance market. For catastrophic events, insurers have a better knowledge of the risks than insureds, due to a reverse information asymmetry (Kunreuther and Michel-Kerjan, 2008). This informational advantage is similar for reinsurers over insurers.

On the reinsurance market, the WTA are on average 50% lower than the WTP, even more for catastrophic events, which rejects hypothesis H2 for the reinsurance market. Insurers mainly transfer their catastrophic risks to the reinsurers. Moreover, reinsurers have a better expertise in assessing risks of extreme events, and deeper opportunities to mutualize the risks than insurers. Insurance professionals are sophisticated respondents answering questions about their field of experience (re/insurance) and their heart of business (assessing risks); then they reason very much differently from the general public.

3.4.4 The effect of the justification on the insurance decisions

In corporations, professionals always have to justify their decisions. In insurance companies where risk management is the core work, the decisions are about the assessment of the risks. In the context of the Solvency II regulation, insurance professionals must even more than before try to justify their decisions, because they now have to document their risk assessment method [11]. Then, even if people have some degree of freedom - and therefore of subjectivity - in their decision, the final decision must be in line with the top management strategy, and they anticipate this fact. This kind of formal justification does not exist for the insurance demand decisions of homeowners.

10. The three major Cat models available on the market are very expensive.

11. This raises the question to know if the risk assessment methods have changed in time since the implementation of Solvency II.

Table 3.5: Insurance premium according to the ease of the justification to others

	Mean		**SD**		**% of individuals**	
	Easy	*Difficult*	*Easy*	*Difficult*	*Easy*	*Difficult*
B - Insurance Supply	1.32	1.99	1.00	1.14	81%	19%
C - Reinsurance Demand	1.68	2.95	1.55	3.62	72%	28%
D - Reinsurance Supply	1.19	1.54	0.93	0.34	85%	15%
Total	1.40	2.15	1.16	1.96	79%	21%

Note: The table displays the average insurance premium according to the ease of the justification to others. Easy refers to an easy choice to justify to others (variable of 1 or 2); difficult refers to a difficult choice to justify to others (variable of 3 or 4).

Table 3.6: Justification of the respondent's choices to others

		Risk	**Imprecision**	**Conflict**
B - Insurance Supply	*mean*	2,19	2,21	2,27
	sd	0,48	0,42	0,48
C - Reinsurance Demand	*mean*	2,24	2,41	2,46
	sd	0,53	0,62	0,63
D - Reinsurance Supply	*mean*	2,12	2,21	2,30
	sd	0,30	0,32	0,43
Total	*mean*	2,18	2,28	2,34
	sd	0,44	0,45	0,51

Note: The table displays the average value (and the standard deviation) on a four point scale. Respondents had to tell how easy (1= very easy to 4=very difficult) it would be to justify their choice of premium to others (e.g. their manager). In this sense, the justification questions were only asked to the professional questionnaires (B, C and D).

Respondents were asked to determine the ease they would have to justify their decisions to others in professional situations. Indeed, it is important for them to base their decisions on accurate information, even more with the new regulation obligations. Insurance actors do not reason only with the probability and the loss amount, they also take into account other factors, quantitative and qualitative, such as the result stability or the solvency constraints. Kunreuther et al (1993) underline the fact that insurers are more willing to be ambiguity averse when they have to justify their decisions to others. Curley et al (1986) report a greater ambiguity aversion when people know they have to justify their decisions. The fact that the information is not complete makes people feel incompetent in convincing others of their choices. In the insurance business, people are assessed by others, and then how easy it is to justify the decisions can influence the behaviors. Insurance professionals are experts of risk assessment and usually follow formal procedures in order to set premiums (Staw, 1980). In case of extreme event, the risks are hardly assessable, this can explain the risk transfer, but also raises the premiums. In our data-set, the justification effect is correlated at 35% with the insurance premiums (p-value of the Student's test of 0), meaning that the easier the justification, the lower the insurance premium. In this sense, respondents who set very high premiums, and therefore who exhibit high aversions, have more difficulty justifying their choice.

Table 3.5 reports the average premium according to how easy the justification is. It is interesting to note that no-one responded that it was "very easy" (corresponding to 1) to justify any of the questions, the minimum response being "easy" (corresponding to 2). Furthermore, we can see that 79% of the individuals consider the justification as easy. Meanwhile, the insurance premiums are much higher when insurance professionals consider that the justification to others is difficult. In addition, the average premium is higher for the reinsurance demand questionnaire, as well as the percentage of individuals considering the justification as difficult. Table 3.6 reports the average justification across the information types, and shows that the decisions are much easier to justify under risk than under ambiguity and even more difficult when the ambiguity is growing. Furthermore, the justification is easier under imprecision than under conflict. This fact goes in the line with Smithson (1999) and Cabantous et al (2007) that find that people feel more competent with consensual than with controversial information.

It appears more difficult for insurance professionals to justify their choices on the demand side (as reinsurance buyer) than on the supply sides (as re/insurance sellers). Being seller could ease the justification because they can refuse to underwrite the risks or at a very high price if they do not feel entirely comfortable with the risk. Furthermore, insurers seem to have more ease justifying their decisions facing man-made events; and reinsurers facing natural catastrophes. It could be explained because insurers are closer to their clients' business and might better know their risk, while reinsurers better assess the catastrophic risks due to their larger diversification capacity and wider scope of expertise (they mostly cover extreme events present in distribution tails).

In a Bayesian world, people are supposed rational and knowing all possible states, then, in case of new information, they update their priors. However, the fact to justify their choices makes people think about them. In the insurance industry, insurance professionals have constantly to document and explain their decisions, even more with the new European regulation (Solvency II). This asks the question about the belief formation. Gilboa et al (2012) suppose that two processes coexist: *raw preferences* and *reasoned choices*. The first one refers to the automatic preference between two choices, without reasoning. The second process implies analyzing a situation before making a choice, so the decision-maker needs to think before deciding. Gilboa et al (2012) explain that life situations can cope with both types of belief formation, depending on how frequent or original the situations are, the second type of situation needing more reasoning. Furthermore, the justification to others are easy when both choices and beliefs are reasoned, because they can base their defense on objective evidence. But the decisions are much more difficult to justify when the beliefs are in contrast with the evidence, or when the choices are in contrast with the reasoning process. In the insurance industry, reasoned choices can be difficult under ambiguity and beliefs can step in, but the justification is more delicate. The problem is that no one knows which information (here, probability) to trust, and it might be more rational to admit that the information is not sufficient.

3.4.5 Explanatory factors of insurance decisions

Insurance decisions depend on objective risk characteristics such as the type of risk and the probability of loss, the exposure, the terms of the insurance contract; on risk subjective perception, and on individual preferences (Petrolia et al, 2011). The individual preferences are influenced by the demographic characteristics such as the age, the marital status, the number of children, the level of education, the income and the past experience (Guiso and Jappelli, 1998). In their work context, insurance professionals should also be influenced by the risk assessment strategy of the top management, the level of capital and the default risk of the insurance company.

The third column of Table 3.8 in Appendix reports the results of a regression, and shows that the premium can be explained at 24%. As seen in the previous findings, the insurance premium increase with imprecision and even more with conflict, and the pollution risk shows lower premium than the windstorm risk. Furthermore, the insurance premium increases with the harder the justification, and the fact of having an Actuary's degree, i.e a risk assessment expertise; however it decreases with the years of experience in insurance. This variable's effect can be explained by the learning process which improves the assessment with the experience. The premium is lower for the reinsurers, but higher on the supply side, which is coherent with H2 and the fact that the reinsurance market is more mature and works differently. An important effect is that the premium increases with the past experience regarding extreme events, in line with the empirical literature (Einhorn and Hogarth, 1986; Hogarth and Kunreuther, 1989). Kahneman et al (1982) point out that individuals appreciate the likelihood of rare events contingent on their past experience, which leads either to overestimate or to underestimate the expected risk. Finally, the individual characteristics influence the insurance decision. The premium increase with the age (in line with the years of experience), the number of children, and decrease with the fact of being in couple. Women and separated individuals have lower premiums, which is different than the expected effect, but it is due to the low number of women and separated individuals in the sample.

The insurance decisions do not only lean upon the need for protection through an arbitrage between the costs and benefits. Other explanations for insurance decisions were found reading the comments (20% of the respondents wrote comments). Most comments were about how they had trouble responding because they could not differentiate the experts and would have wanted a degree of confidence in each expert's position. Under conflict, some respondent wanted a third expert or knowing which expert was in the company. With controversial information, people think that the disagreement is due to the expert's incompetence and credibility, which is difficult to assess even in real life. Other comments explained that they did not have enough information on the business and risks, they would have wanted the level of capital, the geographic correlations, the possibilities of diversification or the market price. Anyway, all comments had practical perspective into the insurance business. Respondents also explained how they defined their premiums in actuarial terms [12], even for the insurance demand questionnaire, which denotes the specificity of this sophisticated population, and confirms hypothesis H4 that they are looking for more objective information.

What is interesting is to compare this specific population with a comparable population. We clearly cannot compare directly the insurance professionals with the representative population of Chapter 2 as their characteristics are really different. However, in order to understand "how different" insurance professionals are from "ordinary insureds", we can compare the insurers and reinsurers with a subsample of the representative population having similar characteristics. We have chosen to select the individuals being graduated, i.e. having at least 4 years of education after high school (having at least a M1 degree in the French educational system). We can see in Figure 3.5 that the structure per gender, age, marital status and number of children of the subsample is closer to the one of insurance professionals, than the full representative population. However, there are some differences: the insurance professional sample has more males, more single individuals, less children and is younger. Table 3.7 in Appendix reports the average WTP of both subgroups. While insurance professionals exhibit risk, ambiguity and conflict aversion, the ordinary graduated insureds do not exhibit differences according to the information type.

The second column of Table 3.8 report the regression on the subgroup of graduated persons of the representative population. The variables explain 38% of the insurance premium, a much higher coefficient of determination than the one in Chapter 2 for the representative population. Nevertheless, the effect of the variables gives similar results. We can note that the terrorism perception is a significant variable, i.e. a proxy for pessimism, while this variable is not significant for the insurance professionals. They reason less on subjective risk perception than "normal" individuals. The first column of Table 3.8 reports a regression with fixed effect on both the insurance professionals and ordinary graduated insureds. The coefficient of determination drops to 15% as we do not all variables due to

12. They reason as the possible loss multiplied by the probability plus an additional loading percentage. The probability was either the more pessimistic estimate, or a mixture of the two estimates. The loading percentage was between 10% and 50%. The more the ambiguity, the higher the loading percentage.

group differences. We can see that the only variable that is highly significant (and with a same effect) in the three regression is the experience in windstorm risk.

3.5 Conclusion

Of particular interest here is whether the insurance decisions is fundamentally different for precise, imprecise and controversial extreme events, and what insurance professionals decide regarding their possible position on the markets of insurance and reinsurance. Our results provide the evidence that insurance professionals are a sophisticated population that behaves differently than the "normal" respondents, as they answered questions in relation with the day-to-day practices in their professional life. Their behaviors differ from the ordinary insureds of the previous Chapter. As a sophisticated sub-population, they have a technical expertise in insurance and use their knowledge outside their work, reasoning with actuarial terms. They are more willing to buy insurance than the general public. However, they face similar biases, and have difficulties assessing imprecise and conflicting situations. Insurance professionals exhibit risk, ambiguity and conflict aversions. They are more willing to buy and sell insurance under risk than under imprecision or conflict. Furthermore, the refusals to purchase or to underwrite insurance increase with ambiguity. On the demand sides, it is a linked to a deny of ambiguous extreme events while on the supply sides, it is linked to market behaviors, insurers knowing that a very high premium won't be accepted.

The demand premiums are lower than the supply ones on the insurance market; while they are higher on the reinsurance market, a market in which the insurer knows the reinsurer has better knowledge of the risks. Furthermore, agents seem to be more risk averse on the reinsurance market and more ambiguity averse on the insurance market. The reinsurance market appears to be more technically advanced compared to the insurance market, with a greater expertise in the transfer of extreme risks. Moreover, the easier the justification, the lower the premium. Indeed, the results are coherent with the ease people can justify their decisions and to what extent they feel competent differentiating the experts. The justification is easier to make under risk than under imprecision, and than under conflict. In addition, it is easier to justify on the supply side than on the demand side because they can easily refuse to bear the risks as suppliers. Finally, the justification is easier regarding events in which agents feel competent (man-made events for insurers because they are closer to the business, and natural ones for reinsurers because they have better expertise).

Individuals do not use the same rational process in the demand and the supply sides of the market. They use more reasoned choices when they have to justify their decisions, but it is sometimes difficult to reason properly under ambiguity with the lack of objective evidence (Gilboa et al, 2012). The results can be put in relation with the way insurers collect information. Insurers seem to always want more information, they want to collect all available information in order to be well-informed. If following the new Solvency II Directive, the insurers need to assess the risks in the best possible way, and then be aware of all possible information regarding these risks. It is linked to the unknowable information hypothesis of Chow and Sarin (2002) that uncertainty is more acceptable when the information is not available at all. However, more information does not always mean a risky one, and in the insurance business, it can wider the ambiguity as they take into account data that was not taken into account before. This collection can lead to greater conflicting information, and the insurance industry need to know that the higher the ambiguity, the greater the premiums... while the insurance demand does not necessarily follow. Then, the communication need to be enhanced, in order to reconcile supply and demand beliefs regarding the possible risks and the ambiguity surrounding these risks.

We hope that this field study, carried out with a sample of professional non-academic respondents and dealing with natural choices for them, can contribute to a further understanding of risk and ambiguity attitudes, and of the effects of information types on insurance decisions. Ambiguity, that is created by changes in climate or in regulation for instance, weakens the risk mutualization mechanisms on the insurance and reinsurance markets and increase aversions of insurance professionals. These events with unknown risk characteristics bring to light two important questions. The first one refers to how to integrate behaviors into rational choices of risk transfer. The second question concerns the communication regarding uncertain events in order to overcome common biases and improve the market efficiency.

3.6 Appendix

3.6.1 Other tables and figures

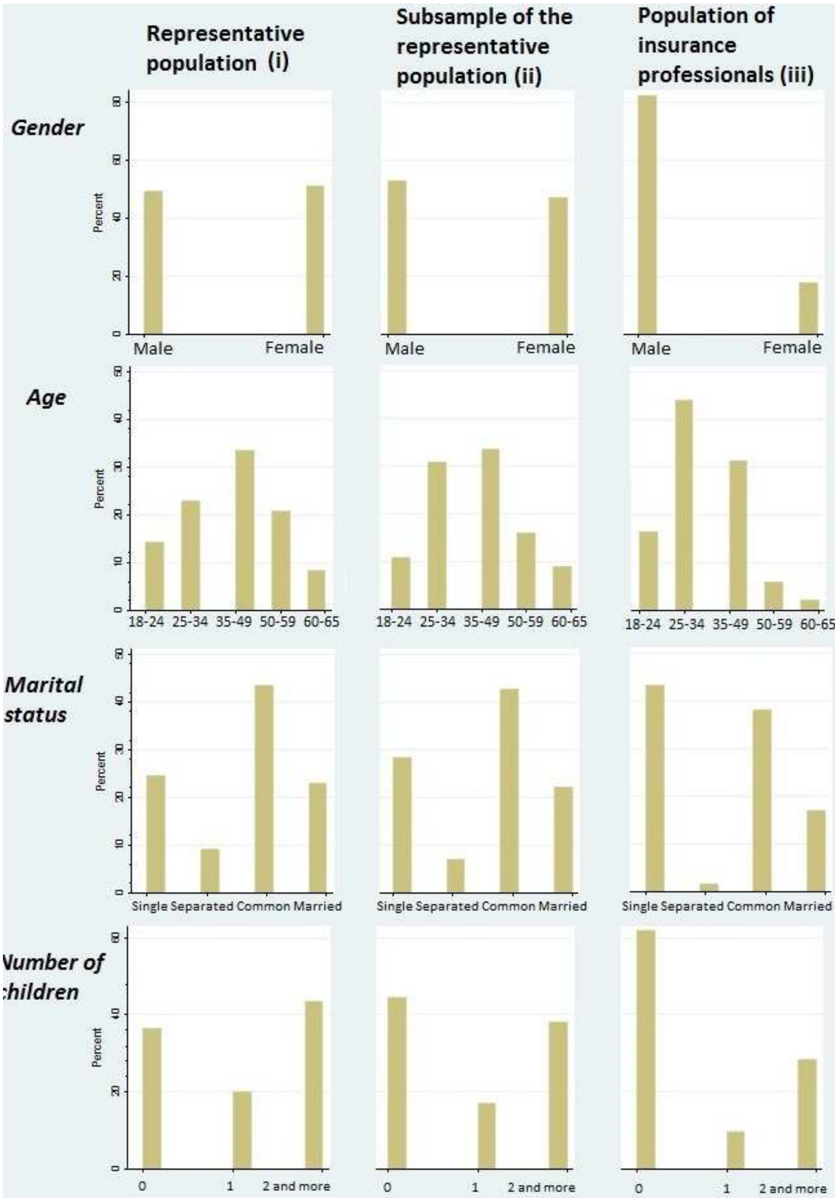

Figure 3.5: Distribution of the respondents according to the group and to their individual characteristics

Note: This figure displays the distribution of individual characteristics in the three different groups: the insurance professionals, the representative population of Chapter 2, and a sub sample of this last group with only the individuals with a high level of education (from the M1 in the French system).

Table 3.7: Insurance WTP in the different risk scenarios according to the group

	Subgroup of the representation population (n=244)						**Insurance professionals** (n=134)					
	R	I1	I2	C1	C2	Total	R	I1	I2	C1	C2	Total
Windstorm risk	**1,10**	**1,11**	**1,09**	**1,08**	**1,11**	**1,10**	**1,10**	**1,32**	**1,36**	**1,37**	**1,43**	**1,32**
	4,20	*4,42*	*4,62*	*5,05*	*5,09*	*4,67*	*0.39*	*0.81*	*1.03*	*0.88*	*0.99*	*0.85*
Pollution risk	**0,88**	**0,89**	**0,89**	**0,87**	**0,70**	**0,85**	**1.17**	**1.31**	**1.31**	**1.22**	**1.30**	**1.26**
	4,75	*5,09*	*4,85*	*5,07*	*4,18*	*4,80*	*0.70*	*0.79*	*0.87*	*0.86*	*0.99*	*0.84*
Total	**0,98**	**1,00**	**0,99**	**0,97**	**0,90**	**0,97**	**1.14**	**1.32**	**1.34**	**1.29**	**1.36**	**1.29**
	4,49	*4,77*	*4,73*	*5,05*	*4,64*	*4,74*	*0.57*	*0.80*	*0.95*	*0.87*	*0.99*	*0.85*

Note: This table display the average premiums in the two different risk scenarios (windstorm and pollution event) for two relatively comparable groups: the insurance professionals and a subgroup of the population sample of Chapter 2 being graduated, i.e. having at least 4 years of education after high school (having at least a M1 degree in the French educational system).

Table 3.8: The effects of control variables on the insurance premiums: OLS regression

	All subgroups (n=378)		**Subgroup of the representative population** (n=244)		**Insurance professionals** (n=134)	
	Coef.	**Std. Err.**	**Coef.**	**Std. Err..**	**Coef.**	**Std. Err.**
Gender (M vs F)	0,366 *	0,223	0,858 **	0,367	-0,448 *	0,252
Age (<25 years old)						
25-34 years old	-2,025 ***	0,581	-12,237 ***	2,020	0,727 **	0,344
35-49 years old	-2,012 ***	0,600	-12,190 ***	2,026	1,398 ***	0,526
50-59 years old	-1,762 *	0,938	-8,921 ***	1,973	2,427 ***	0,739
60-65 years old	-4,361 ***	1,024	-10,961 ***	2,041	0,099	1,014
Socio-economic group (Low)						
High	-0,008	0,363	-0,978	0,673	0,426	0,292
Without activity (retired, student)	4,597 ***	1,177	-2,649 **	1,139		
Marital status (Bachelor)						
Separated or divorced	-1,915 ***	0,584	-2,959 ***	1,150	-1,628 ***	0,497
Married	-0,522	0,448	-1,429	1,264	-0,079	0,278
Common life	-1,255 ***	0,351	-0,906	1,051	-1,014 ***	0,290
Number of children (0)						
1	1,235 **	0,565	2,707 **	1,142	1,094 ***	0,307
2 and more	0,165	0,224	0,253	0,383	1,175 ***	0,315
Experience in windstorm risk	1,211 ***	0,330	1,828 ***	0,658	1,758 ***	0,381
Experience in pollution risk	-0,407	0,260	-0,538	0,514	-0,283	0,278
Insurance claim	0,220	0,269	1,853 ***	0,549	-0,719 ***	0,237
Perception of terrorism level	0,716 ***	0,183	2,360 ***	0,484	0,070	0,244
Event (Windstorm vs Pollution)	0,486 *	0,257	1,227 **	0,478	-0,317 *	0,191
Information (Risk)						
Imprecision	0,272	0,271	0,081	0,551	0,377 *	0,237
Conflict	0,317	0,277	0,168	0,556	0,449 *	0,249
Group (Representative pop.)						
Insurer	-0,204	0,183				
Reinsurer	-0,666 ***	0,259				
Market side (Demand vs Supply)	1,270 ***	0,253			1,600 ***	0,324
Income level (<1600€)						
1601-3000€			-5,731 ***	1,245		
3001-7600€			-5,425 ***	1,723		
>7600€			-7,138 ***	1,516		
Refusal to respond			-6,079 ***	1,472		
Region of France (South-West)						
Ile de France (Region of Paris)			-0,319	0,543		
North-East			1,728 **	0,700		
North-West			1,180	0,874		
South-East			0,771	0,541		
Justification					0,869 ***	0,227
Insurance experience (year)					-0,101 ***	0,026
Actuarial degree					0,494 **	0,229
Reinsurance formation					-0,217	0,218
Insurer vs Reinsurer					-1,649 ***	0,309
Constant	-0,245	0,592	11,001 ***	2,263	1,045 *	0,635
R^2	**0,148**		**0,378**		**0,239**	

$*$ if $P \leqslant 0.1$, $**$ if $P \leqslant 0.05$, and $***$ if $P \leqslant 0.01$

3.6.2 Questionnaires (in French)

3.6.2.1 Questionnaire pour le "grand public"

Petites consignes avant de démarrer

Tout d'abord merci de participer à cette enquête sur le comportement d'assurance. Il s'agit d'une étude scientifique sur la prise de décision. Ce projet de recherche est soutenu par l'Université Paris 1 Panthéon-Sorbonne et servira de support pour une thèse de doctorat en économie. Compléter cette enquête prendra entre 12 et 15 minutes selon vos réponses. L'objectif est d'étudier comment les individus prennent des décisions dans des situations de risque que l'on peut rencontrer dans la vie personnelle et/ou professionnelle. Vous devez considérer les situations hypothétiques comme des situations réelles. Certaines situations proposées peuvent vous paraître extrêmes ou peu réalistes. Ce qui m'intéresse est votre décision par rapport à ces situations. Il n'y a pas de bonnes ou de mauvaises réponses. Cette enquête est totalement anonyme. Les résultats de l'enquête ne seront publiés que sous une forme agrégée. Si vous désirez les recevoir une fois celle-ci terminée, vous pourrez laisser une adresse mail. Je vous prie de lire attentivement les instructions et de répondre le plus sincèrement possible. Merci d'avance pour votre participation.

Fonctionnement de l'assurance

L'assuré transfert un risque, par définition aléatoire, à la compagnie d'assurance. La compagnie d'assurance accepte le risque en échange d'une prime. L'assuré est alors protégé contre des évènements qu'il ne veut pas supporter seul. Le mécanisme de l'assurance ne modifie pas la probabilité de survenance du risque et ses conséquences. La compagnie d'assurance réalise une mutualisation des risques entre les assurés à travers la souscription de nombreux risques similaires. Cette gestion du risque permet à l'assureur de rembourser l'ensemble des sinistres que ses assurés subiront grâce aux primes payées en amont.

Votre rôle

Vous êtes à la tête du département gestion des risques d'une grande entreprise possédant plusieurs locaux. Vous êtes chargé(e) de définir les contrats d'assurance que vous pouvez acheter afin de vous protéger contre des risques particuliers. Autrement dit, vous choisissez la couverture contre les pertes liées à des sinistres potentiels.

Le contexte

Votre entreprise cherche à s'assurer contre des risques spécifiques. Elle peut faire face à deux sortes de risques:

- Le risque de tempête,
- Le risque de responsabilité civile environnementale

Votre entreprise possède plusieurs locaux. Il s'agit ici d'analyser le risque de ces locaux afin de les assurer de manière indépendante.

Les caractéristiques du risque

Deux caractéristiques du risque sont à prendre en compte:

- Le montant total des pertes
- La probabilité annuelle de survenance d'un risque

Avis des experts

Pour avoir une vision plus précise du risque, vous faites appel à plusieurs experts. En se basant sur l'activité de l'entreprise et sur des logiciels de modélisation, ils estiment pour chaque local la probabilité annuelle de survenance d'un risque (tempête ou responsabilité civile environnementale).

Trois cas peuvent se présenter:

- Les experts sont d'accord entre eux, ont une idée précise du risque et fournissent une probabilité unique.
- Les experts sont d'accord entre eux, ont des difficultés pour estimer le risque et fournissent une estimation imprécise pour la probabilité.

- Les experts ne sont pas d'accord entre eux pour estimer le risque et fournissent chacun une probabilité précise.

L'évaluation du montant des pertes ne pose aucun souci aux experts.

1ère caractéristique du risque: Le montant total des pertes

Les pertes sont la somme que coûte le sinistre.

- En cas de tempête, les pertes associées comprennent les pertes directes assurées (destruction d'entrepôts, de machines,...) et les pertes d'exploitation consécutives au sinistre, évaluables à partir du chiffre d'affaires, déduction faite des franchises.
- En cas d'une pollution mettant en cause la responsabilité civile de l'entreprise, les pertes associées comprennent les dommages matériels et immatériels occasionnés à des tiers et les frais de dépollution.

2ème caractéristique du risque: La probabilité de survenance d'un risque

La probabilité annuelle de survenance d'une tempête ou d'une responsabilité civile environnementale est de X Votre mission Pour chaque situation décrite, en tant que directeur du département gestion des risques, il vous est demandé de fixer le montant maximum de la prime d'assurance annuelle que vous êtes disposé à payer pour vous couvrir totalement. Cette couverture totale vous garantira un remboursement intégral en cas de sinistre. Toutefois, vous avez toujours la possibilité de refuser de vous assurer. Dans ce cas, vous supportez vous même la totalité des pertes. Après chaque réponse, il vous est possible de faire un commentaire, mais vous n'y êtes pas obligé. Par exemple, vous pouvez expliquer comment vous avez fixé le montant de la prime, pourquoi vous avez refusé de vous protéger contre un risque, ou encore sous quelles conditions vous changeriez d'avis.

A vous de jouer!

[Les deux risques suivants sont dans un ordre aléatoire]

Le risque de tempête

Dans cette série de 5 questions, votre entreprise cherche à s'assurer contre le risque de tempête. L'entreprise possède plusieurs locaux répartis dans différentes régions. L'intensité du risque peut varier en fonction du type de construction, du degré d'exposition, du risque de la région, des mesures de protection et de prévention mises en place, etc.

[Série de 5 questions (dans un ordre aléatoire) sur ce risque de la forme suivante]

- Quelle est la prime d'assurance maximum que vous êtes prêt à payer pour vous protéger totalement contre ce risque durant une année (mettre 0 si vous refusez de vous couvrir): ...

- Commentaires éventuels: ...

Figure 3.6: Représentation des questions pour le risque de tempête

Le risque de responsabilité civile environnementale

Dans cette série de 5 questions, votre entreprise utilise des produits chimiques toxiques dans le processus de fabrication et cherche à s'assurer contre le risque de responsabilité civile environnementale. Votre entreprise possède plusieurs locaux et respecte les normes en vigueur concernant l'utilisation de produits dangereux. Toutefois, vous n'êtes pas entièrement à l'abri qu'une fuite apparaisse et qu'un produit toxique s'échappe de l'enceinte d'un local et pollue les sols aux alentours.

[Série de 5 questions (dans un ordre aléatoire) sur ce risque de la forme suivante]

– Quelle est la prime d'assurance maximum que vous êtes prêt à payer pour vous protéger totalement contre ce risque durant une année (mettre 0? si vous refusez de vous couvrir): ...

– Commentaires éventuels: ...

Figure 3.7: Représentation des questions pour le risque de pollution

Caractéristiques individuelles

- Vous êtes: *Un homme / Une femme*
- Quelle est votre année de naissance? ...
- Quelle est votre profession? ...
- C'est-à-dire: *Agriculteur exploitant / Artisan, Commerçant, Chef d'entreprise / Cadre et profession intellectuelle supérieure / Profession libérales / Profession intermédiaire, Technicien, Contremaître et agent de maîtrise / Employé / Ouvrier / Retraité / Sans activité (étudiants, chômeurs,...)*
- Travaillez-vous dans une société d?assurance? *Oui / Non*
- Vous habitez en: *Ile de France / Normandie, Centre, Pays de la Loire, Bretagne, Poitou-Charentes / Nord Pas-de-Calais, Lorraine, Alsace, Franche-Comté, Champagne Ardennes, Picardie, Bourgogne / Aquitaine, Midi Pyrénées, Limousin / Rhône Alpes, Auvergne, Languedoc Roussillon, PACA, Corse*
- Votre Code Postal: ...
- Vous êtes: *Célibataire / Marié(e) / Divorcé(e) ou séparé(e) / Vie commune*
- Combien d'enfants avez-vous? ...
- Quel est votre niveau de diplôme le plus élevé? *Sans diplôme ou Brevet des collèges / BEPC / CAP ou BEP / Baccalauréat général, technologique ou professionnel / Diplôme de niveau Bac + 2 (DUT, BTS, DEUG, écoles des formations sanitaires ou sociales,...) / Licence (Bac+3) / Licence professionnelle (Bac+3) / Diplôme National de Technologie Spécialisé (Bac+3) / Master 1 (Bac+4) / Master 2 professionnel (Bac+5) / Master 2 recherche (Bac+5) / Master 2 enseignement (Bac+5) / Diplôme d'ingénieur (Bac+5) / Doctorat (Bac+8)*
- Quel est le montant des revenus nets mensuels de votre ménage? *Moins de 1100€/ 1100 à 1600€/ 1601 à 2300€/ 2301 à 3000€/ 3001 à 4600€/ 4601 à 7600€/ Plus de 7600€/ Refus de répondre*

- Avez-vous, vous ou un de vos proches, subi des dommages liés à une tempête? *Oui / Non*
- Considérez vous que cela a changé votre point de vue de l?assurance des risques de

tempête? *Oui, beaucoup / Oui, un peu / Non*

- Avez-vous, vous ou un de vos proches, subi des dommages liés à une pollution environnementale causée par une entreprise? *Oui / Non*
- Considérez vous que cela a changé votre point de vue de l?assurance de responsabilité civile environnementale? *Oui, beaucoup / Oui, un peu/ Non*
- Considérez-vous le risque de terrorisme en France à un niveau: *Très fort / Fort / Faible / Très faible*
- Avez-vous fait une déclaration de dommage auprès de votre compagnie d?assurance pendant les 3 dernières années? *Oui / Non*
- Il s'agissait d?un dommage relevant de votre contrat d?assurance: *Automobile / Multirisque habitation / Garantie accident de la vie / Autre*
- Autre contrat d'assurance: ...
- Quel était approximativement le coût du dommage déclaré? ...
- Quels sont vos suggestions ou commentaires sur cette enquête? ...

3.6.2.2 Questionnaire pour les "professionnels de l'assurance"

[La structure est la même que le questionnaire précédent. Les informations ci-dessous montrent seulement les différences.]

A - Questionnaire sur la demande d'assurance

[Même que précédemment]

B - Questionnaire sur l'offre d'assurance

[Questionnaire symmétrique au précédent]

Votre rôle

Vous êtes à la tête du département gestion des risques dans une grande compagnie d'assurance. Vous êtes chargé(e) de la souscription des risques pour des clients qui cherchent à se couvrir contre les pertes liées à des sinistres potentiels. Vous allez considérer le cas de certains risques de votre portefeuille.

Votre mission

Pour chaque situation décrite, en tant que directeur du département gestion des risques dans une grande compagnie d'assurance, il vous est demandé de fixer le montant minimum de la prime d'assurance annuelle que vous êtes disposé à offrir . Il s'agit de la prime pure, c'est-à-dire la prime qui ne correspond qu'à la compensation des sinistres et ne prend en compte, ni les chargements de gestion, ni l'intensité de la concurrence .

Dans les différentes situations, lorsque vous acceptez de couvrir un risque à un prix donné (vous pouvez toujours refuser), vous devez considérer qu'il n'y a pas de possibilités de réassurance ou de coassurance.

Après chaque réponse, il vous est possible de faire un commentaire , mais vous n'y êtes pas obligé. Par exemple, vous pouvez expliquer comment vous avez fixé le montant de la prime, pourquoi vous avez refusé de couvrir un risque, ou encore sous quelles conditions vous changeriez d'avis (plafond de remboursement, coassurance, réassurance).

A vous de jouer !

Le risque de tempête

Dans cette série de 5 questions, une entreprise cherche à s'assurer contre le risque de tempête. Cette entreprise possède plusieurs locaux répartis dans différentes régions. L'intensité du risque peut varier en fonction du type de construction, du degré d'exposition, du risque de la région, des mesures de protection et de prévention mises en place, etc.

Le risque de responsabilité civile environnementale

Dans cette série de 5 questions, une entreprise utilise des produits chimiques toxiques dans son processus de fabrication et cherche à s'assurer contre le risque de responsabilité civile environnementale. Cette entreprise possède plusieurs locaux et respecte les normes en vigueur concernant l'utilisation des produits dangereux. Toutefois, elle n'est pas à l'abri qu'une fuite apparaisse et qu'un produit toxique s'échappe de l'enceinte d'un local et pollue les sols aux alentours. Cette pollution accidentelle peut-être dangereuse pour les habitants de la région et mettre en cause la responsabilité civile environnementale de l'entreprise.

[Formulation des questions/]

- Quelle est la prime d'assurance minimum que vous êtes prêt à accepter pour couvrir ce risque durant une année? (mettre 0 si vous refusez d'assurer le risque): ...

C - Questionnaire sur la demande de réassurance

[Ce questionnaire n'est posé seulement si l'individu est familier avec la réassurance.]

Votre rôle

Vous êtes à la tête du département gestion des risques dans une grande compagnie d'assurance. Vous êtes chargé(e) de définir des contrats de réassurance que vous pouvez acheter afin de vous protéger contre des risques particuliers. Autrement dit, vous choisissez la couverture de votre compagnie d'assurance contre les pertes liées à des sinistres potentiels.

Votre mission

Pour chaque situation décrite, en tant que directeur du département gestion des risques dans une grande compagnie d'assurance, il vous est demandé de fixer la valeur maximale du taux de prime que vous êtes disposé à payer pour vous couvrir contre le risque décrit sur la dernière tranche d'un traité de réassurance.
Il s'agit d'un Rate on Line (RoL), c'est-à-dire du rapport de la prime versée au réassureur sur la portée de la tranche : RoL = Prime / Portée
Dans les différentes situations, vous avez toujours la possibilité de refuser de transférer le risque au réassureur.Après chaque réponse, il vous est possible de faire un commentaire, mais vous n'y êtes pas obligé. Par exemple, vous pouvez expliquer comment vous avez fixé le RoL demandé, pourquoi vous avez refusé de transférer un risque, ou encore sous quelles conditions vous changeriez d'avis (tranche, possibilité de rétrocession). A vous de jouer !

[Formulation des questions:]

- Quel est le RoL maximum que vous êtes prêt à payer pour cette tranche haute? (mettre 0 si vous refusez de vous couvrir): ...

D - Questionnaire sur l'offre de réassurance

[Ce questionnaire n'est posé seulement si l'individu travaille dans une compagnie de réassurance.]

Votre rôle

Vous êtes à la tête du département gestion des risques dans une grande compagnie de réassurance. Vous êtes chargé(e) de la souscription des risques pour des clients (principalement des compagnies d'assurance) qui cherchent à se couvrir contre les pertes liées à des sinistres potentiels. Vous allez considérer le cas de certains risques de votre portefeuille.

Votre mission

Pour chaque situation décrite, en tant que directeur du département gestion des risques dans une grande compagnie de réassurance, il vous est demandé de fixer la valeur minimale du taux de prime que vous êtes disposé à offrir pour assurer le risque décrit sur la dernière tranche d'un traité de réassurance.
Il s'agit d'un Rate on Line (RoL), c'est-à-dire du rapport de la prime versée au réassureur sur la portée de la tranche : RoL = Prime / Portée
Dans les différentes situations, vous avez toujours la possibilité de refuser de couvrir le risque de l'assureur. Après chaque réponse, il vous est possible de faire un commentaire, mais vous n'y êtes pas obligé. Par exemple, vous pouvez expliquer comment vous avez fixé le RoL demandé, pourquoi vous avez refusé de souscrire au risque, ou encore sous quelles conditions vous changeriez d'avis (tranche, possibilité de rétrocession). A vous de jouer !

[Formulation des questions:]

- Quel est le RoL minimum que vous êtes prêt à accepter pour couvrir cette tranche haute? (mettre 0 si vous refusez d'assurer le risque): ...

Caractéristiques individuelles

[Questions similaires que dans le questionnaire "grand public", ainsi que des questions sur le métier d'assurance des individus.]

- Depuis combien d'années travaillez-vous dans le secteur de l'assurance? *... années*
- Quel est votre secteur d'activité? *Conception et adaptation de produits / Contrôle technique et prévention Gestion des contrats Commercial Comptabilité Réassurance Administration Secrétariat et assistanat / Communication / Gestion des actifs / Informatique et télécommunications / Etudes et conseil Gestion et organisation / Logistique / Ressources humaines / Direction / Autre secteur d'activité: ...*
- Gestion des contrats, c'est à dire: *souscription émission / production / encaissement des cotisations gestion polyvalente souscription / production indemnisation / règlement gestion polyvalente souscription / production / règlement recouvrement de créances sur des tiers qualité et surveillance du portefeuille suivi des risques en assurance-crédit gestion des décomptes maladie / Autre gestion des contrats: ...*
- Commercial, c'est à dire: *vente des contrats aux guichets / vente des contrats dans un réseau salarié / vente directe et souscription par téléphone / vente aux guichets et gestion polyvalente / vente hors guichets et gestion polyvalente / animation ou gestion de guichets agences générales ou cabinets de courtage / encadrement d'un réseau salarié / Autre Commercial: ...*
- Quelle est votre branche d'activité? *Dommages / Vie capitalisation / Santé / Multibranches / Autre branche d'activité: ...*
- Quels types de risques gérez-vous? (plusieurs réponses possibles) *Automobile / Responsabilité civile / Catastrophe / Vie / Autres risques : ...*
- Avez-vous un diplôme d'actuaire? *oui / non*
- Quels sont vos domaines de diplômes? (plusieurs réponses possibles) *Finance, banque, assurance / Commerce, vente, marketing, distribution / Droit et sciences politiques / Secrétariat, bureautique / Comptabilité, gestion / Mathématiques et sciences / Informatique, traitement de l'information, réseaux de transmission / Economie et sciences sociales / Autres domaines: ...*

CHAPTER 4

Insurance behaviors facing different information types: An experimental investigation

Work in cooperation with Sébastien Massoni, Ph.D. candidate, Université Paris1 Panthéon-Sorbonne

4.1 Introduction

Individuals behave differently in the presence of risk and ambiguity (Ellsberg, 1961), and also according to the ambiguity source, separating here attitudes toward imprecision and conflict. Imprecision refers to a situation in which the information is consensual but imprecise; and conflict refers to a situation of disagreement between experts. Conflict aversion (Smithson, 1999) appears when individuals prefer a consensual information over a controversial one, conflicts being perceived as less credible. On the insurance market, where the evaluation of the risk characteristics (the potential losses and the occurrence probabilities of an event) is the core topic, conflict aversion has been found for insureds (Chapter 2) and insurers (Chapter 3). However, these papers report results from questionnaires with no real incentives. To our knowledge, there does not exist experimental evidence of comparable decisions on the supply and on the demand side of the insurance market under risk, imprecision and conflict.

This paper brings a complementary approach to the previous chapters of this thesis. Non incentivized surveys allow to studies the behaviors of a large sample of real people dealing with real-life situations. These people do not necessarily have knowledge of probabilities and represent a very heterogeneous group. On the other side, economics experimentation analyzes smaller and more homogeneous samples, usually students with knowledge of probabilities, that receive incentives to reveal their choices. Experiments can highlight behaviors present in the real-life situations, even if the samples are not representative of the population. Both approaches are complementary in order to reveal specific aspects of the insurance behaviors. We conduct an experiment with monetary incentives that allows to understand how the type of information impacts the insurance decisions on both sides of the market. In order to link the insurance results to individual characteristics, we use new psychological variables and define personality traits of our subjects. All this will give us an overall picture of insurance buyers and sellers behaviors with respect to which information is available for their decision.

By comparing insurance premiums under different information types (risk, imprecision, conflict, and imprecise conflict), we will be able to identify a ranking of decisions on these events. We go further in the analysis by checking whether this ranking is robust to changes in the characteristics of the decision: the case of rare events, the side of the market, the increase of information's divergence. Subjects take decisions regarding low-probability high-consequence (LPHC) and high-probability low-consequence (HPLC) events. They face four information types regarding the occurrence probability according to the position of two experts. Under risk, the experts agree that the probability is well-known and precise. Under imprecision, they agree that it takes a range of possible values, but they cannot narrow down the estimation because of lack of information. Under conflict, the experts do not have the same information, they disagree and each has its own precise estimate. Finally, under imprecision within conflict, they disagree and each expert gives its own but imprecise estimate. We vary the bounds, holding an expected value of 500 euros, which generates three events by information type and by event level, allowing us to test for growing ambiguity aversions. The subjects play two experimental sessions relative to both market sides: a demand experiment in which they choose their coverage against possible losses and a supply one in which they subscribe insurance contracts. BDM mechanisms (Becker et al., 1964) are used to elicit willingness to pay (WTP) and to accept (WTA), quantities of contracts bought and sold, and subjective probabilities of events realization. This design enables to obtain complete information about insurance choices (prices, quantities and subjective probabilities). Subjects are paid according to their performance on a contract relative to a benchmark based on expected-value maximizer's behaviors. Finally, we control for framing effects with comparable questions on a gambling context, as well as for the subjects' risk and loss aversions, past experience, and personality traits (thanks to the Big Five Inventory framework).

Our results provide evidence that behaviors are different according to the information types. We come up with a ranking of insurance premiums across the information types ($\pi_R < \pi_I \leqslant \pi_C < \pi_{IC}$), that appears to be more significant for buyers than for sellers. The results also show that LPHC events are more underestimated than HPLC events, and that people are more willing to buy insurance for more likely events. Furthermore, demand and supply premiums are very different, the WTP being much lower than the WTA. The WTA-WTP gap is higher for extreme events, and smaller under ambiguity. In addition, there are more purchasing and less selling under ambiguity than under risk, as subjects on the demand side are more willing to buy insurance and subjects on the supply side are less willing to sell insurance under ambiguity. This means that when adding ambiguity, the price increases but the traded quantity is relatively stable. The possible exchanges are larger for HPLC than for LPHC events. Furthermore, framing effects are important across events, across contexts, and across question forms. Finally, insurance decisions are strongly affected by risk attitudes, personality traits and past experience.

The chapter is structured as follows. The second section presents the predictions from economic intuition. The third section summarizes the main points of the empirical literature on decision making under ambiguity in insurance. The following section introduces the experimental design and the incentives. The fifth section presents the results in function of the predictions. Finally, the chapter discusses the results from the control variables, and raises questions for further research.

4.2 Predictions

In this section we specify a set of hypotheses and provide economic intuition for each of them, as the theoretical background regarding insurance market experiments is not well developed on the literature.

The experimental design test for ambiguity and conflict aversion, in order to know how subjects respond to different ambiguity sources. Subjects should set higher insurance premiums under ambiguity than under risk, in line with the theoretical literature summarized in Chapters 2 and 3. Furthermore, we expect subjects to respond differently facing imprecision and conflict. Indeed, why should they consider as the same a situation where two experts agree on an interval of probability and a situation where these experts disagree and each gives a bound of the interval? The expected loss is the same, but the information processing is different. Behaviors are affected by the confirmation bias. Then, people tend to search for and interpret information in a way that confirms their preconceptions. Between an imprecise and a conflicting situation, subjects should choose the imprecise situation as both experts confirm each other estimate of the probability. How to trust experts that have completely different estimates? Buying subjects will pay more in order to get rid of a conflicting risk, and selling subjects will charge more in order to accept to bear this risk. Therefore, subjects prefer consensual over controversial information, because conflicts are perceived as less credible and trustworthy.

The experiment sets up buying and selling subjects. We expect the buying prices to be lower than the selling prices. Demand and supply reservation prices do not necessarily have to be same, especially when an actuarial fair price cannot exist due to ambiguous probabilities. First, a buyer always want to pay the minimum amount and a seller to get the maximum one, in order to respectively maximize their income and profit. Second, following the Prospect theory, loss and gain situations are considered as different. The buying subject pays an insurance premium and gets rid of a risk which he did not want to bear. The selling subject gets the premium but has to pay in case of an event, and the loss he will have to pay is much higher than the premium. Third, in order to benefit from the risk mutualization effects, the selling subject should not underestimate the risk, as a misunderstanding of the risk can lead to severe consequences on his profit. On the demand side, the subject can be willing to pay a very low insurance premium (or not take insurance at all) if he underestimates the risk and thinks it will not happen to him.

This risk underestimation is linked to the under-insurance problems of our societies, especially for extreme events. People tend to ignore low probability events as these events are difficult to imagine, to analyze and to deal with. They usually buy insurance right after such an event occurs, but cancel their policy after a few years without a risk. This well-known myopic behavior makes us expect subjects to buy insurance for more likely events and to deny rare threats. Selling agents might have similar behaviors, but to a lesser extent.

In addition, framing effects are analyzed. Subjects have to make choices about insurance and about lotteries, these being considered as a "neutral" context. Insurance questions are related to real-life situations, then we expect stronger responses than in the lottery context. This means that the aversions will be stronger, the prices higher and the results more significant.

Then, let consider the following hypotheses. In addition to the hypotheses already defined in Chapters 2 and 3 (H1 and H2), we test for two other hypotheses (H3 and H4) which are specific to our experiment.

H1. Premiums given in the experiment can be ranked regarding the information types ($\pi_R \leqslant \pi_I \leqslant \pi_C \leqslant \pi_{IC}$.)

H2. The premium payed on the demand side of the controlled insurance market are lower than the premium asked on the supply side ($WTP \leqslant WTA$).

H3. Subjects behave differently facing LPHC and HPLC events. They are willing to pay and to accept higher insurance premiums for HPLC than for LPHC events.

H4. Subjects react differently facing an insurance framing and a lottery framing.

The design of our experiment allows to test these hypotheses and thus to characterize how individuals behave facing insurance choices. The main goal is to define insurance behaviors under risk and ambiguity, for likely and extreme events, on the demand and supply sides of the market.

4.3 Literature review

As mentioned in the previous chapters, individuals exhibit risk and ambiguity aversions facing insurance questions in surveys on the demand side (Hershey and Schoemaker, 1980; Hogarth and Kunreuther, 1985) and on the supply side of the market (Hogarth and Kunreuther, 1992; Kunreuther et al, 1993). Separating the ambiguity sources, Chapter 2 and Chapter 3 respectively investigate how the general public and insurance professionals behave under imprecision and conflict, and find a preference for consensual information and a dislike for conflicts. These papers study insurance behaviors through non-incentivized questionnaires. To our knowledge, there is no paper with an experimental approach analyzing both insurance demand and supply under several ambiguity sources. It is interesting to compare the degrees of risk, imprecision and conflict aversions for both sides of the market in order to check the demand and supply behaviors.

In the empirical literature, only a couple of papers studied insurance behaviors separating demand and supply decisions. Einhorn and Hogarth (1986) and Hogarth and Kunreuther (1989) analyze the buyers' willingness to pay and the sellers' willingness to accept under risk and ambiguity. They observe that both buyers and sellers exhibit ambiguity aversion, and that sellers exhibit more ambiguity aversion than buyers. Insurance sellers even refuse to subscribe insurance contracts when the ambiguity is too strong. They explain that sellers give more weight to high losses than buyers. Indeed, the agent bearing the risk has to give more attention to the risk characteristics because a misunderstanding can lead to severe consequences. Furthermore, ambiguity aversion decreases when the occurrence probability increases. It even becomes ambiguity seeking for insurance buyers. In addition, past experience is a significant variable of insurance demand. Hogarth and Kunreuther (1989) compared responses from students and insurance professionals in their experiment and find that insurance professionals are more sensitive to ambiguity than students, but the differences between the two groups are relatively small. These papers studied demand and supply behaviors under ambiguity, but the ambiguous information is not defined, they include ambiguity through comments explaining the uncertain situation around a best estimate, which creates a strong anchor effect.

Empirical studies have analyzed insurance behaviors regarding low and high probability events, revealing that extreme risks lead to different behaviors than more common risks. In presence of well-estimated risks, Slovic et al (1977) maintain that individuals prefer purchasing insurance contracts for large-probability high-consequence events, rather than for low-probability high-consequence events. The possibility of learning over time being limited, the estimation of the occurrence probability cannot always be adjusted. Individuals have a short term vision, they prefer taking protection against most likely losses. In a similar fashion, Hershey and Schoemaker (1980) observe an overestimation of low-probability risks and an underestimation of large-probability risks. A certain bimodality is found in other empirical studies. Kunreuther (1978) studies the willingness to buy insurance and reveals the low percentage of individuals buying insurance against catastrophic event, while people willing to purchase insurance exhibit strong risk aversion. McClelland et al (1993) show that, for low-probability risks, people appear either to dismiss the risks or to worry too much about them. Therefore, the insurance decision does not only lean upon the need for protection through an arbitrage between the costs and benefits. Kahneman et al (1982) point out that individuals appreciate the likelihood of rare events contingent to their past experience concerning the event, which leads either to overestimate or to underestimate the expected risk.

Hogarth and Kunreuther (1985) find ambiguity aversion for low-probability events. As the probability increases, ambiguity aversion decreases and become a preference for ambiguity for large-probability events. As McClelland et al (1993) under risk, Schade et al (2004) also find bimodal behaviors in presence of ambiguity. People are either scared of extreme risks and pay a premium well in excess of the expected loss, or ignore them completely and do not insure. Furthermore, behaviors seem to be even more significant under ambiguity than under risk. People exhibit large ambiguity aversion and tend less to dismiss the risks of extreme events. There are no studies analyzing framing effects under conflicting situation.

Regarding the framing effect between an insurance context and a lottery one, Hershey and Schoemaker (1980) highlight a strong insurance context effect on risk aversion. Individuals choose more systematically the safer option coping with insurance questions, than with non-contextual lotteries. Similar results are found for insurers (Kunreuther et al, 1995). Risk aversion seems stronger in a real environment like insurance, rather than in a neutral context. Kunreuther et al (2001) explain that individuals are more likely to express a decision from probabilistic data when they also have qualitative information. Framing strongly affects the ability to use probabilities in order to express a judgment.

Then, the empirical literature on insurance decision facing extreme events brings to light that people behave differently in the presence of risk, imprecision and conflict, that they face difficulties in interpreting small probabilities and do not only reason based on the expected value. However, these papers are neither comparable, nor based on experimental evidence with real incentives, as it is in the loss domain with low probability events.

4.4 Experimental design

The design of the experiment has variations in the subjects' roles (buyers or sellers of insurance), the task (elicit prices, quantities and beliefs) and the available information (risk, imprecision, conflict and imprecise conflict for HPLC and LPHC events). It results in a $4 \times 2 \times 2$ design organized as follows. First, subjects give their certainty equivalent and subjective beliefs facing multiple lotteries. Then, they play as buyers and are asked to reveal their WTP and quantities facing low and high probability events. Finally, after a short break, they play as sellers and reveal their WTA and quantities facing the same events. We describe here the design (see the Appendix for details) and the incentives.

4.4.1 Sources of information

During all the experiment, subjects face the same pattern of information in order to take their decisions. We vary the source of information available on the events' probability, giving us four types of information as summarized in Table 4.1. We present the probabilities in terms of two experts' opinions for helping subjects understand the changes of situations. Under risk (R), the probability of the event is precise and well-estimated, both experts agree on this value. Under imprecision (I), the experts agree but their best estimate of the probability is imprecise. They cannot narrow down the estimation because of lack of information, so they give a range of possible values for the occurrence probability. Under conflict (C), the experts do not have the same information or do not use the same tools, they disagree on the value of the probability and each expert has its own precise estimate. Finally, under imprecision within conflict (IC), the experts disagree and each expert gives its own range of possible values of the probability. In order to help subjects we add a graphical representation of the probability in each case (see Table 4.1).

In each information type, there are two kinds of events (see Table 4.2): a low probability high consequence (LPHC) event and a high probability low consequence (HPLC) event. We present both events as being "natural", the LPHC event being a windstorm damaging an entire building, and the HPLC event being hail falling on a car. As we want to estimate the event impact on insurance and beliefs, we keep a same expected value for both events.

Table 4.1: Four types of information

The experts are ...	Precise	Imprecise
In agreement	**Risk (R)** p The experts use the same information, and the risk is exactly assessable.	**Imprecision (I)** $[p_{min}; p_{max}]$ The experts use the same information, but the risk is vaguely assessable.
In disagreement	**Conflict (C)** $(p_1; p_2)$ The experts do not use the same information, but the risk is exactly assessable for each of them.	**Imprecision within conflict (IC)** $([p_{min1}; p_{max1}]; [p_{min2}; p_{max2}])$ The experts do not use the same information, and the risk is vaguely assessable for each of them.

Table 4.2: Two types of events

	LPHC event *Low probability / high consequences*	**HPLC event** *High probability / low consequences*
Average probability	5%	25%
Loss amount	10,000€	2,000€
Expected value	500€	500€

For all events and each type of information, subjects face three levels of probability with an increase in the gap between the experts' estimate. Figure 4.1 displays the probabilities used in LPHC event (a similar range of values centered on 25% is used for HPLC event). Note that the ambiguous situations need to be compared with R2. Overall, subjects take decisions under 24 different levels ($2 \times 4 \times 3$) of probabilities that allow to analyze several aspects of insurance choices.

4.4.2 Insurance decisions

Subjects have different decisions to take in this experiment (see the Appendix for the detail). There are two distinct insurance parts, respectively referring to insurance demand and insurance supply. In the first insurance part, they have a role of insurance buyers: they have to decide the insurance coverage for specific and independent risks of a big company

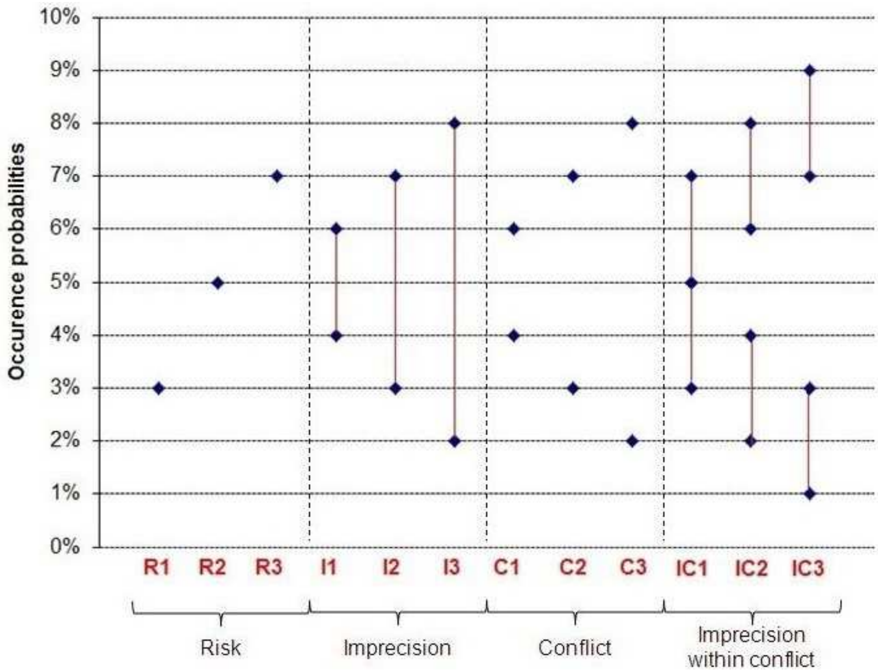

Figure 4.1: Levels of probability of the LPHC event

(their own). Their objective is to minimize the insurance costs. Their arbitrage is to choose between buying insurance, paying the premium and be protected against adverse events; or not subscribing insurance and risking the loss in case of adverse event. Then, after a short break, a second insurance part is played in which the subjects become insurance sellers.

They have to decide the subscription for specific and independent clients of an insurance company. Their objective is to maximize the insurance performance. Their arbitrage is to choose between selling insurance, gaining the insurance premium, but paying the loss in case of adverse event for the client; or not underwriting insurance, receiving and paying nothing.

In each part, they take three decisions:

1. The insurance premium, i.e. how much are you willing to pay (WTP) or to accept (WTA) for each contract:
   – On the demand side: *What is the maximal insurance premium that you are willing to pay to be covered against this risk?*

  - On the supply side: *What is the minimal insurance premium that you are willing to accept to cover this risk?*

2. The insurance quantity, i.e. how many contracts over 100 they are willing to buy or to sell:
   - On the demand side: *For each possible price, how many insurance contracts are you willing to buy, out of 100?*
   - On the supply side: *For each possible price, how many insurance contracts are you willing to sell, out of 100?*

3. The estimation of the probability, i.e., based on the experts' assessment and according to them, which probability will be realized. The formulation is the same in both sides: *What probability do you consider as equivalent to the expert' opinion?*

4.4.3 Elicitation mechanisms

Contrary to a large majority of experiments on insurance, we provide monetary incentives to reveal subjects' choices, which implies two aspects of the setting: to define a payment scheme and to chose some probability generators for the different types of information. For the last point, subjects know that the realized probability under imprecision will be generated by an uniform distribution [1] and under conflict by a quantum generator i.e. a true random bit generator [2]. Therefore, the subjects know the distributions of the possible occurrence probabilities, but they cannot predict the one which will be realized for sure.

For the payment scheme, subjects are paid according to their relative performance against an automatic program that behaves as an expected-value maximizers. Table 4.3 and Table 4.4 summarize the calculation of the performance for the price and quantity

1. Even if some recent papers develop new methods to generate ambiguity (Stecher et al, 2011; Hayashi and Wada, 2010), we follow Halevy (2007) and consider that imprecision could be generated via an uniform distribution.
2. The TRBG has the advantage to appear more unpredictable for subjects while it follows asymptotically an uniform distribution. For this experiment we use sequences from random.org.

Table 4.3: Performance in the price part

	Event occurrence	If insurance	If no insurance
Buyers	No	$-Premium$	0
	Yes		$-Loss$
Sellers	No	$Premium$	0
	Yes	$Premium - Loss$	

Table 4.4: Performance in the quantity part

Buyers	$-$ *Price* $*$ *Quantity of insured risks* $-$ *Losses for occurred and non insured risks*
Sellers	*Price* $*$ *Quantity of insured risks* $-$ *Losses for occurred and insured risks*

Note: These tables display the calculation of the performance. In each part (price and quantity) and market side (demand and supply), we calculate the performances for both the subject and the computer, and compare them in order to assess the subject's payment.

parts. Subjects know that they are in competition with a computer that possess the same information, that will have the same possible losses (if a risk occurs to them, it will also occur to the computer), and that will always choose the expected value of the risk, i.e. €500. The computer can be seen as a competitor in the same company that want to take the subject's job and runs parallel analyses in order to see if she will be better. At the end of the experiment, we assess the subjects and computers' performances for each insurance part, and compare both performances. If a subject has chosen the same value as the computer, she will receive a fixed and relatively low gain compared to the gain she would have had with a different value. This incentive mechanism allows to elicit beliefs in the loss domain with extreme events. We are not allowed to make subjects lose money, and it is not possible to give the subjects an initial endowment due to the low occurrence probabilities of our risks.

Insurance premiums are revealed with a Becker-Degroot-Marschak (BDM) mechanism (Becker et al, 1964) in which subjects choose their WTP and WTA in a pre-determined list of prices (Kahneman et al., 1990). The premiums are compared to a market price determined by a random number generator. For insurance demand, if the subject's premium is greater than the market price, she pays the price and is insured. If the subject's premium is lower than the market price, she pays nothing and is not insured. The mechanism is symmetric for insurance supply. In our experiment, if the subject has chosen a different premium than the computer, a market price is randomly drawn and a BDM mechanism reveals who has insurance (only the subject, only the computer, both, or none). The subject's gain depends on the difference between its performance and the computer's performance. The subjects know all possible situations and the gain they will obtain in each of them. For example, on the insurance demand side, if the subject has chosen a price equal to $\pi_{subject}$ (the computer's price is $\pi_{computer} = 500$) and that the drawn market price is π_{market} with $\pi_{subject} < \pi_{market}$, the BDM mechanism says that the computer will be insured but the subject won't. If there is no loss, the subject's gain is €20 because she was right not to take insurance. If a loss occurs, her gain is null. On the opposite, if the subject is insured but not the computer, her gain is $24 - \frac{\pi_{market}}{100}$ in case of loss (because she was right to take insurance), and $20 - \frac{\pi_{market}}{100}$ if no loss (which encourages the subject to buy insurance). For the questions about insurance quantity, one price is randomly drawn and the performances are calculated. The gain is increasing with the subject's performance, and is of €20 if both performances are equal, and up to €40 if the subject incurs no loss at all.

In addition, a third incentivized part is played in which subjects reveal their behavior in a more "neutral" frame: lottery. We use the same pattern of probabilities as in the insurance frame (24 choices with high and low levels in the four types of information). Subjects have to respond to three sorts of questions about gambling with lotteries. First, they have to reveal their certainty equivalents facing risky or ambiguous lotteries (for different prices in a list, do they prefer playing the lottery or paying the price?). Then, they have to determine their preferences between couples of lotteries (which lottery do they rather want to play between two lotteries with specific characteristics?). Finally, we elicit their subjective beliefs for all 24 lotteries (which probability do you consider as equivalent to the expert's opinion?). The elicitation of subjective beliefs is done through the Probability Matching Mechanism (i.e. to exchange a lottery based on subjective probability by an objective one

- see Hollard et al, 2011 and references therein). Therefore, the lottery part gives us the certainty equivalents, the elicited probabilities, and the preferences between two options. This design allows to study the importance of the insurance frame by comparing two different contexts: an insurance and a lottery one, the latter being considered as more "neutral".

For the final payment, we randomly draw one of the choices in the lottery part and pay according to the answer (they can gain up to €10). In each insurance part (demand and supply), we randomly draw one insurance choice (in price or in quantity) and pay with respect to their relative performance (they can gain up to €40 in each part). Including the flat payment of €5 subjects can win a maximum amount of €95.

4.4.4 Control variables

Before the experiment begins, we ask subjects questions in order to create different control variables. We elicit individual indexes of risk and loss aversions (Holt and Laury, 2002). To do so, we ask subjects what they prefer between two options: playing a lottery (for instance, 50% chance to gain €10) and a sure amount (for instance, gaining a sure amount that varies between €0 and €10). They make their choice for three levels of probability (30%, 50% and 70%), and two framings (gains and losses).

Furthermore, we elicit an index of impatience; and personality traits using the Big Five Inventory framework (BFI, the French version by Plaisant et al., 2010) in an hypothetical way. We use the locus of control[3], as well as two domains of the BFI: conscientiousnes which is the degree to which a person is willing to comply with rules, and neuroticism, which is the degree to which a person sees the world as dangerous (Borghans et al, 2008). We also ask for past experience and opinions about insurance and extreme events.

3. Four questions that are part of a psychometric questionnaire of 29 items developed by Rotter (1966). So this is a very partial measure of the personality trait of control.

Table 4.5: WTP and WTA for insurance in the different treatments

		R1	**R2**	R3	**I1**	**I2**	**I3**	**C1**	**C2**	**C3**	**IC1**	**IC2**	**IC3**
WTP	*mean*	297	381	470	376	401	450	407	408	451	401	424	464
	normalized mean	0,99	**0,76**	0,67	**0,75**	**0,80**	**0,90**	**0,81**	**0,82**	**0,90**	**0,80**	**0,85**	**0,93**
	sd	0,48	0,33	0,26	0,35	0,35	0,37	0,34	0,35	0,36	0,34	0,35	0,36
	% of refusal	32%	20%	9%	16%	13%	12%	19%	14%	12%	16%	10%	12%
WTA	*mean*	389	464	531	447	471	498	461	459	487	457	471	511
	normalized mean	1,36	**0,82**	0,64	**0,80**	**0,85**	**0,93**	**0,92**	**0,92**	**0,97**	**0,91**	**0,94**	**1,02**
	sd	0,48	0,30	0,23	0,30	0,29	0,32	0,31	0,28	0,33	0,31	0,30	0,30
	% of refusal	3%	3%	8%	4%	5%	5%	3%	4%	3%	3%	3%	7%
Total	*mean*	343	423	501	412	436	474	434	434	469	429	447	488
	normalized mean	1,17	**0,79**	0,66	**0,78**	**0,82**	**0,91**	**0,87**	**0,87**	**0,94**	**0,86**	**0,89**	**0,98**
	sd	0,48	0,31	0,24	0,32	0,32	0,34	0,33	0,32	0,35	0,32	0,32	0,33
	% of refusal	17%	11%	9%	10%	9%	9%	11%	9%	8%	9%	7%	10%

Table 4.6: Significance of the premiums' differences

	I1	**I2**	**I3**	**C1**	**C2**	**C3**	**IC1**	**IC2**	**IC3**
R2	$=$	$<^{**}$	$<^{***}$	$=$	$<^{**}$	$<^{***}$	$<^{*}$	$<^{***}$	$<^{***}$
I1		$<^{***}$	$<^{***}$	$<^{**}$	$<^{***}$	$<^{***}$	$<^{**}$	$<^{***}$	$<^{***}$
I2			$<^{**}$	$=$	$=$	$<^{***}$	$=$	$<^{**}$	$<^{***}$
I3				$>^{***}$	$>^{***}$	$=$	$>^{***}$	$>^{*}$	$=$
C1					$=$	$<^{***}$	$=$	$<^{***}$	$<^{***}$
C2						$<^{***}$	$=$	$<^{***}$	$<^{***}$
C3							$>^{***}$	$>^{**}$	$=$
IC1								$<^{***}$	$<^{***}$
IC2									$<^{***}$

$*$ if $P \leqslant 0.1$, $**$ if $P \leqslant 0.05$, and $***$ if $P \leqslant 0.01$

Note: Table 4.5 displays the results for the three different levels of the four information types (R, I, C, IC), LPHC and HPLC events together. It shows the mean WTP and WTA (without the refusals, i.e. the "0"), as well as the mean of the normalized premiums (premiums divided by the expected loss), its standard deviations, and the percentage of refusals. Note that the ambiguous situations have to be compared with the R2 column as it has the same expected loss.
Table 4.6 shows the significant differences between the premiums, WTP and WTA together. For example, the last-column last-row cell can be read as the premiums under IC2 are significantly lower than the premiums under IC3. An equal sign means that the differences are not significant.

4.5 Results

4.5.1 Data-set

These results are based on five sessions of around 15 subjects each, with a total of 73 subjects. All sessions were conducted at the Laboratory of Experimental Economics in Paris (LEEP) of the University of Paris 1 between July 2012 and February 2013. The experiment was programmed and conducted on Regate (see Zeiliger, 2000). The experiments last around 3 hours (including a 30 minutes break) and subjects were paid €40 on average. First, we are going to analyze the attitudes towards different information types. Then, we focus on demand and supply behavior, and on framing effects.

4.5.2 The effects of information type on insurance premiums (H1)

The type of available information affects the willingness to pay and to accept of insurance. Table 4.5 presents the results of the experiment and Table 4.6 the significant differences. Situations under risk (R2) show much lower premiums on both sides of the market than the three ambiguous situations, which tells us that both insurance buyers and sellers exhibit ambiguity aversion. Situations under imprecision within conflict display the highest premiums. The imprecise and conflicting situations lie between the two. The premiums under imprecision are globally lower than the premiums under conflict, but the differences are not always significant (see Table 4.6). Moreover, the amount of money people are willing to pay or to accept increases with the ambiguity level ($\pi_{k1} < \pi_{k2} < \pi_{k3}$, with $\{k = I; C; IC\}$). The findings are that the more ambiguous and complex the information, the higher the insurance premiums. The ranking of premiums that we obtain is $\pi_R < \pi_I \leqslant \pi_C < \pi_{IC}$, in line with H1. Furthermore, the normalized premiums are lower than one, meaning that people do not exhibit risk aversion[4]. This result is surprising, especially for WTA as insurance sellers should be risk averse. A premium lower than the expected loss is not sustainable for an insurer.

4. The only premiums greater than the expected loss are the WTA for R1 and IC3, the situations with the lowest risk, and with the highest ambiguity.

We observed such ranking on the pooled data-set. At an individual level, we found the following results: 2% of the subjects are not sensitive to the nature of information while 74% define a lower premium under R than under IC. The ranking between I and C is less clear with the following distribution: 51% have lower premium under imprecision than under conflict ($\pi_I < \pi_C$), 35% have the opposite ($\pi_I > \pi_C$) and 13% are indifferent between the two situations ($\pi_I = \pi_C$).

When comparing pairs of treatments, it is interesting to see that IC1 and I2 situations are seen as equivalent. People are willing to pay or to accept a similar premium when experts agree on a wide range of values, and when they disagree on intervals and the intervals have a common estimate. Having a common estimate does not change the ambiguity aversion between both situations. On the contrary, when comparing I3 and IC2, people prefer when the range of possible values is smaller, even if the experts disagree. This means that the ambiguity type is not the only explanatory factors of insurance decisions, the extent of the ambiguity matters a lot. A conflicting situation can be preferred to an imprecise one if the conflict between the two experts is not too strong. Overall, we obtain a ranking of insurance premium across the information types ($\pi_R < \pi_I \leqslant \pi_C < \pi_{IC}$), that appears more significant for buyers than for sellers, which confirms H1.

4.5.3 The differences of insurance decisions on the demand and on the supply sides (H2)

Our analysis allows to compare insurance premiums on the demand and supply side of the market under risk and ambiguity. Einhorn and Hogarth (1986) and Hogarth and Kunreuther (1989) distinguish buying and selling decisions, and observe that insurance sellers exhibit more ambiguity aversion than insurance buyers. The results of Table 4.5 show that the insurance premiums on the supply side are on average 11% higher than the premiums on the demand side, as shown in Figure 4.2, which is coherent with H2. If we look at the individual level, the WTA are on average 25% greater than the WTP, which is consistent with hypothesis H2. If we look according per information type, we find that higher premiums differences under risk than under ambiguity: The WTA are 31% greater than the WTP under risk, 24% under imprecision, and 21% under conflict and

Table 4.7: Refusals of buying and selling insurance

	Refusal of buying insurance				**Refusal of selling insurance**			
	R	I	C	IC	R	I	C	IC
LPHC event	29%	21%	25%	20%	4%	4%	2%	4%
HPLC event	11%	5%	5%	5%	5%	5%	5%	5%

Note: The table displays the percentages of subjects refusing insurance. All the differences are significant in the refusals of buying insurance, but not in the refusals of selling insurance.

under imprecise conflict. Figure 4.3 shows the differences between the WTA and the WTP are more dispersed for risk and imprecision, and smaller for conflict and imprecise conflict. The gap between the WTP and the WTA is positive and tend to decrease with ambiguity. This result is different than the one in the Chapter 3. This result can be linked to the absence of mistrust into the insurance industry in the controlled experiment, subjects are more willing to trust the insurance instructions of the experimentation than the insurers in real-life situations. In addition, the gap between WTA and WTP is higher for extreme events than for more likely ones.

In addition, the number of refusals are very different in both sides of the market, with more than three times more refusals to buy insurance than to sell insurance (see Table 4.7). This result cannot be attributed to a mistrust in the insurance industry as in Chapter 2, as the experiment was made in a controlled environment. Subjects not interested in purchasing and selling insurance could have set respectively very low and high premiums (see Figure 4.2). Subjects selling insurance can be tempted to increase the premium and overestimate the risk in order to not to subscribe the insurance contract, and then avoid the winner's curse (Mumpower, 1991).

Regarding the quantities purchased and sold by subjects, a risky information is differently perceived than an ambiguous information, but there are not significant differences between the three ambiguous information type. The quantity part allows us to draw demand and supply curves for insurance, as shown in Figure 4.4 as the subjects had to give the quantity (out of 100) they were willing to buy and sell for different premiums. The main results are that there are more purchasing under ambiguity than under risk, and more selling under risk than under ambiguity. In addition, the more the ambiguity, the

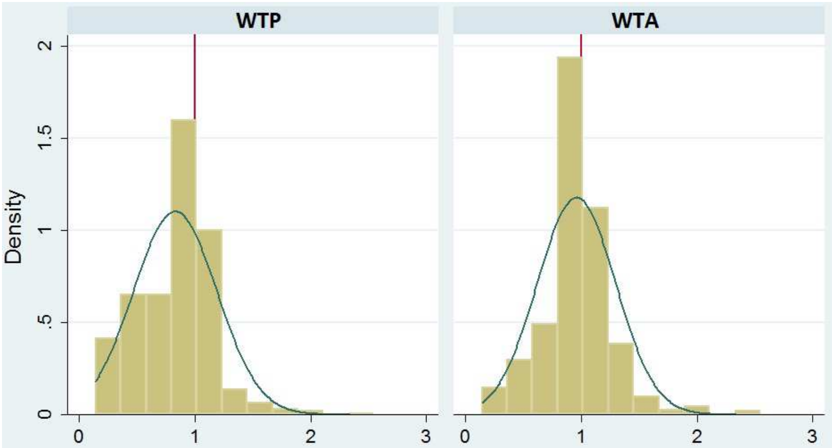

Figure 4.2: Histogram of the WTP and WTA

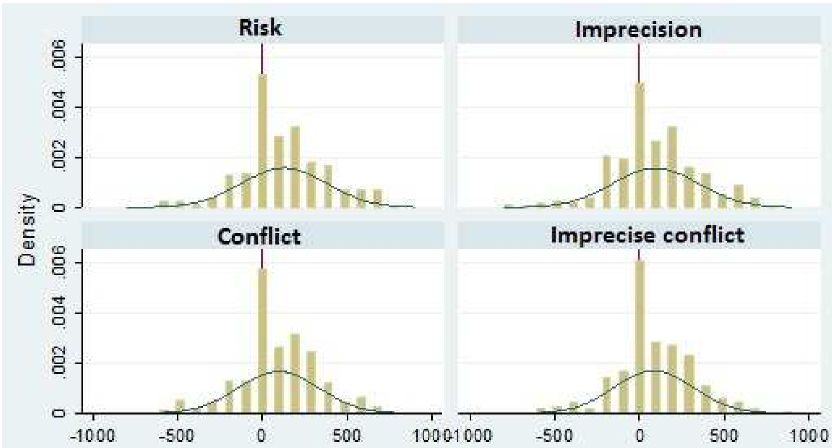

Figure 4.3: Histogram of the differences between WTA and WTP ($WTA - WTP$)

more people subscribe insurance, but the less insurers are willing to underwrite the risks, which leads to an increase of the price. Graphically, the equilibrium between demand and supply moves to the right in presence of ambiguity, as in Hogarth and Kunreuther (1989). The decisions of quantities are highly correlated with the decisions of prices. We can see on Figure 4.4 that demand and supply meet below the expected value of €500, and for a quantity below 50.

In addition, quantities differ for low and high probability events: the variations between risk and ambiguity are smaller for HPLC events, while the quantity is greater. Then, the meeting points between demand and supply are lower for extreme events.

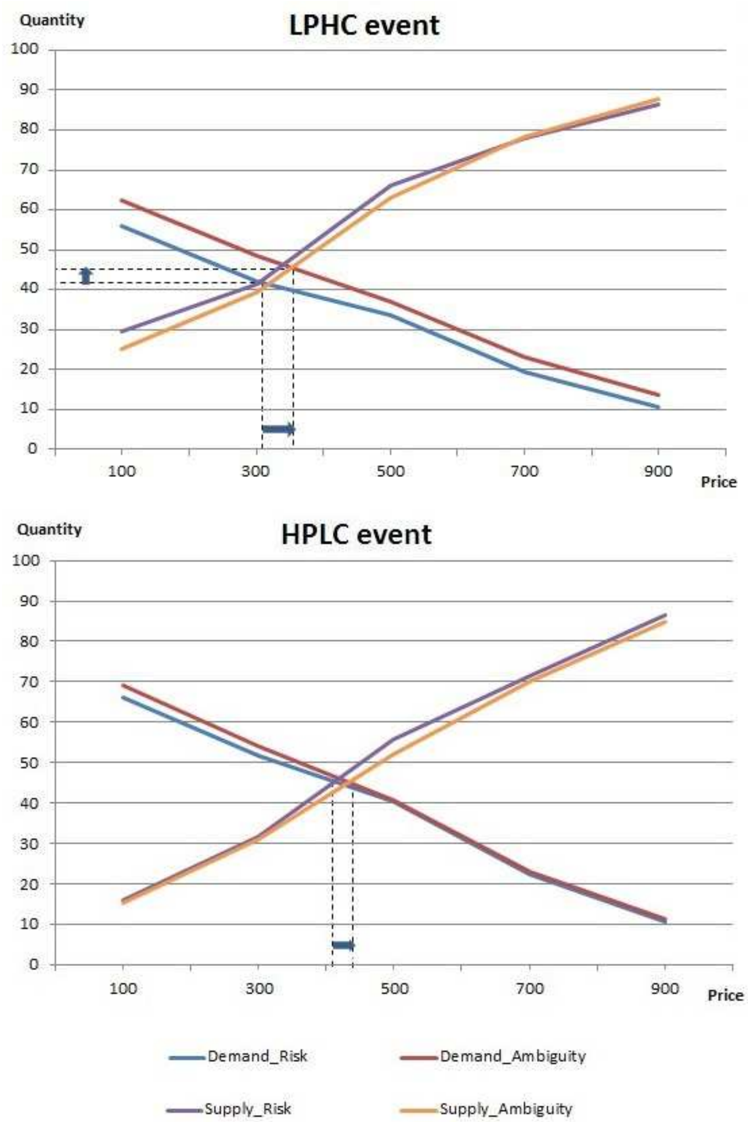

Figure 4.4: Demand and supply curves under risk and ambiguity

Note: This figure displays the demand and supply curves under risk (R) and under ambiguity (the I, C and IC questions all together). Subjects had to give the quantities of insurance contracts (out of 100) they were willing to buy and sell for different prices (100, 300, 500, 700 and 900). The ambiguous situations have been combined because the differences are not significant between the ambiguity types, but they are significant when comparing with the risky situation.

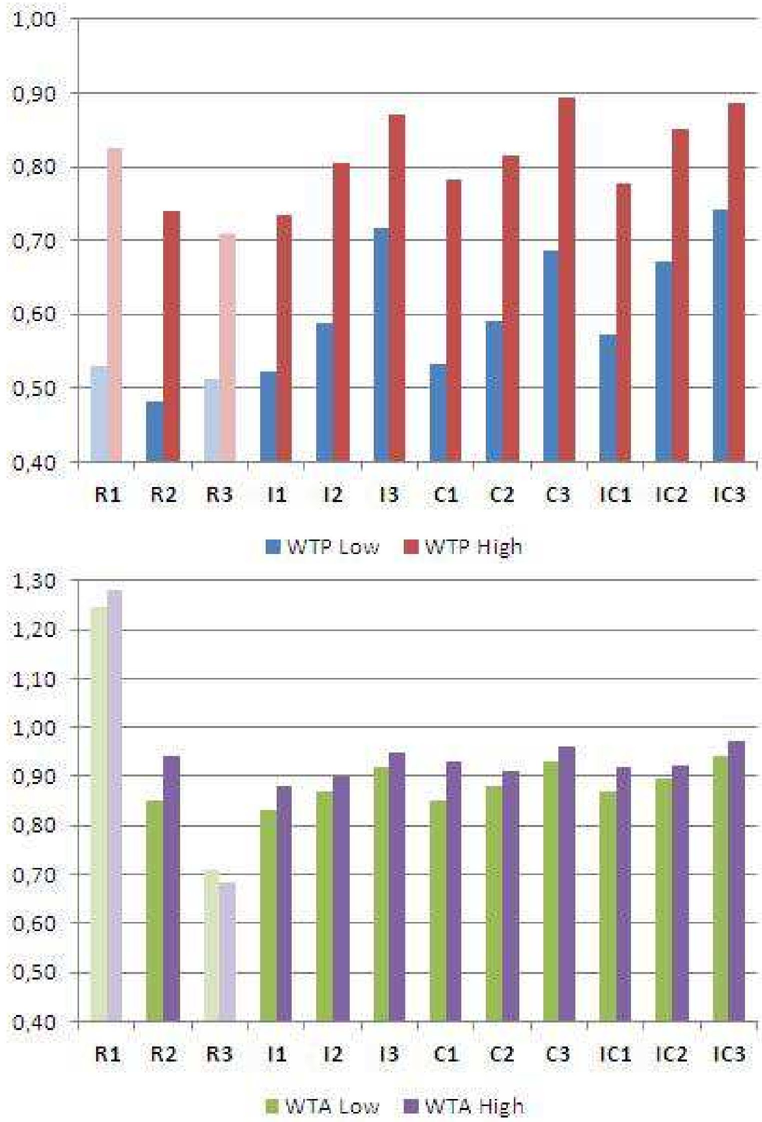

Figure 4.5: Willingness to Pay and to Accept for LPHC and HPLC events

Note: This figure shows the details of the normalized WTP and WTA in the different information types for low probability high consequence and high probability low consequence events (note that I,C and IC have to be compared to R2).

4.5.4 The framing effects of the event and of the context (H3 and H4)

We observe that LPHC and HPLC events are perceived very differently (see Figure 4.5). Subjects' behavior is very different toward extreme or more common events. There is an obvious underestimation of low probability events. Subjects are more willing to pay for most likely losses and deny rare threats, in line with H3 and the empirical literature. The refusals of insurance (see Table 4.7) also show disparities between LPHC and HPLC events. On the demand side, there are much more refusals for low probability events than for high probability events; and the refusals are decreasing when adding ambiguity. People are more willing to buy insurance coverage against ambiguous events, which goes in line with Kunreuther et al (1993), but against Chapter 2's findings who found lower coverage for ambiguous events. The difference is smaller on the supply side of the insurance market, in terms of premiums and looking at the number of refusals. Regarding the WTA/WTP ratios, the average ratio is higher for low probability events, than for high probability events.

Our experiment allows to compare an insurance and a gambling context. Framing effects has been shown in the literature: an insurance context lead to more averse behaviors. This effect can be different for low and high probability events. A framing effect can only be observed when comparing the gambling part of the experiment with the insurance demand one. Figure 4.6 displays the WTP and the certainty equivalents (CE) for both low and high probability events. Here again, the ranking is $CE_R < CE_I \leqslant CE_C < CE_{IC}$, and we observe an underestimation of low probability events compared to most likely ones. We observe high correlations between the WTP and the CE. However, the framing effect is stronger facing lotteries than insurance, the WTP being lower than the certainty equivalents, which is surprising as insurance context seem to disclose stronger aversions in the literature, as it is related to real-life situations.

We can also compare the equivalent probabilities the subjects have chosen in both insurance and gambling contexts. Figure 4.7 shows the subjective probabilities in the insurance demand (MP_D and MP_O) and facing lotteries. Only the subjective probabilities in the gambling context were incentivized but we assume the subjects have responded properly.

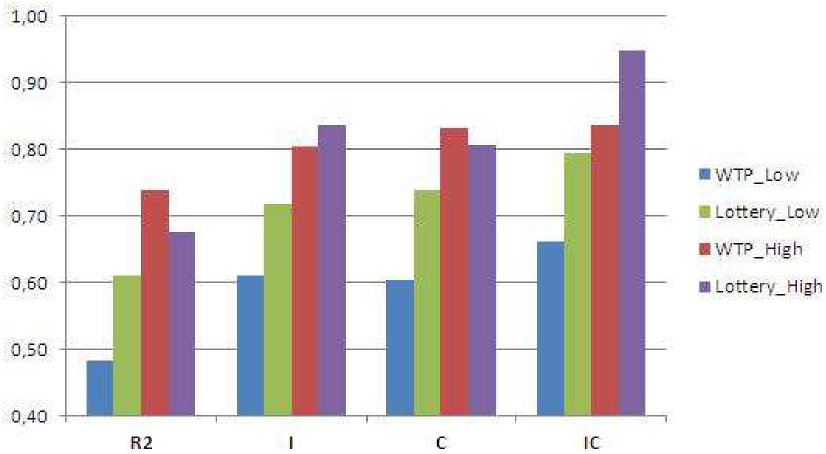

Figure 4.6: WTP and CE for low and high probability events

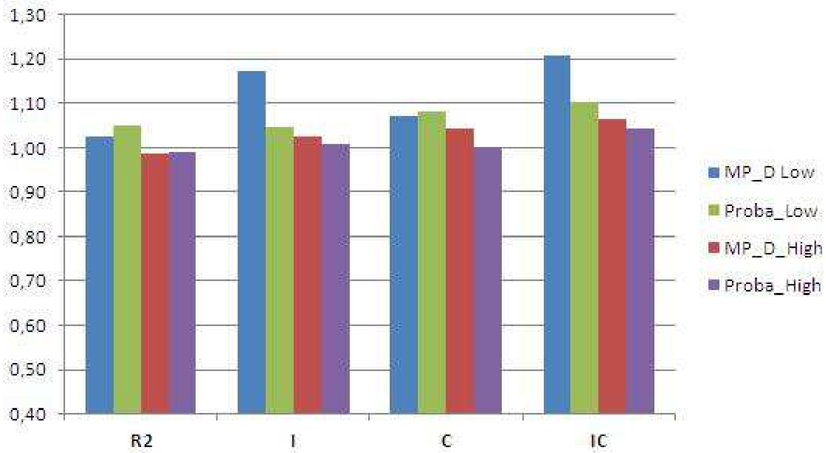

Figure 4.7: Subjective probabilities in insurance and lottery contexts

Table 4.8: Subjects' choices between two options

	R2 vs I2	R2 vs C2	I1 vs I3	I2 vs C2	I2 vs IC1	C1 vs C3	C2 vs IC1	C2 vs IC2	IC2 vs IC3
Option 1	68%	73%	73%	53%	34%	73%	30%	47%	55%
Option 2	21%	17%	14%	22%	26%	17%	45%	36%	23%
Indifference	10%	10%	12%	25%	40%	10%	25%	17%	22%

Note: The table displays the percentages of subjects who have chosen the first option, the second option or who were indifferent between both options. The first information type is the first option, and always corresponds to the "less ambiguous" option.

Both probabilities are closer to each other in HPLC events. In LPHC events, the insurance subjective probabilities are on average higher than the "neutral" subjective probabilities. The framing effect is stronger in insurance. It is quite surprising that the framing effect is stronger in the insurance context when looking at the probabilities, but lower when looking at the prices, which do not entirely verify H4. Moreover, LPHC events are underestimated compared to the HPLC event in terms of prices but overestimated in terms of probabilities.

In addition, we can analyse the gap between subjective probabilities (MP_D, MP_O) and the willingness (WTP, WTA). This gap is lower under risk than under ambiguity (but there are no real differences across I, C and IC); for HPLC events than for LPHC events; for buyers than for sellers; and for low ambiguous than high ambiguous situations. This means that the gap between probabilities and prices increases in more difficult or uncertain situations such as extreme events, supply side of the market, greater ambiguity. This result gives evidence in favor of a less rational process of decision facing complex choices.

Finally, Table 4.8 reports the results of the choices between two lotteries. The preferences are clear, the subjects prefer the first option (which is always the less ambiguous). The ranking over the information types is $R \succ I \succ C \succ IC$. The interesting finding is that, the subjects are quite indifferent between I2 and IC1, which is consistent with the premiums' difference of Table 4.6. Between C2 and IC1, the subjects prefer IC1, because experts have a common estimate.

4.6 Discussion and explanatory factors of insurance decisions

We are looking here at the possible explanations of the insurance premiums. The arbitrage between the risk and the return from the experts' assessment is not the only explanation of insurance decisions. The first explanatory factor is relative to the subjects' beliefs of the occurrence probability (which probability will be realized according to them), that we saw previously in Figure 4.7 for the demand side. These probabilities are significantly and positively correlated at 30% with the premiums.

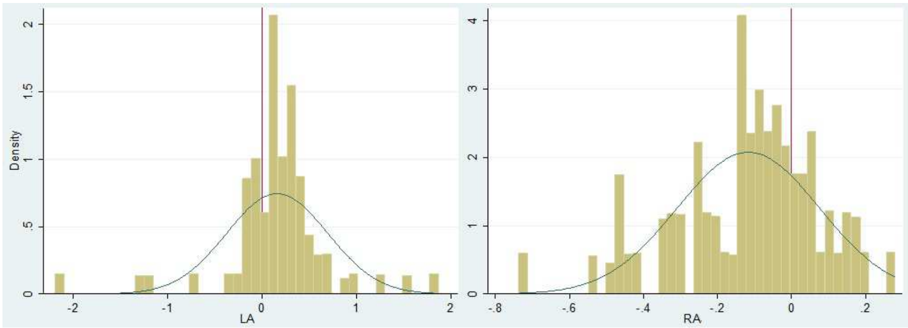

Figure 4.8: Histograms of the indexes of risk and loss aversion

A second set of explanatory factors regroups the subjects' preferences, and in particular the risk and loss aversions. The mean values of risk and loss aversions' index are respectively -0.12 and 0.16 [5], a positive index being an aversion and a negative one a seeking behavior. On average, the subject exhibit loss aversion but risk seeking behaviors. Figure 4.8 displays the distribution of both indexes showing the loss and risk behaviors.

Looking at the individual level, out of 73 subjects, 26% are risk averse, and 73% are risk seeking. Concerning loss behavior, 71% of the subjects are loss averse and 27% loss seeking. Only 18% of the subjects are at the same time risk and loss averse (19% are at the same time risk and loss seeking). The interesting thing is that subjects exhibit risk seeking behavior with lotteries and with insurance questions. In our experiment, the risk aversion index is correlated at 21% with the WTP and 9% with the WTA. Nevertheless, if we only take into account risk averse subjects, the differences between the four information types become all highly significant.

Another set of explanatory factors is relative to a new framework of predictive factors which links personality traits and economics (see Borghans et al, 2008 for a review). Indeed, the personality influences the cognition, and are essential in the way people process information . The most prominent measurement system for personality traits is the Big Five Inventory (BFI) of Costa and McCrae (1992). The BFI combines five broad domains describing personality, derived from a factor analysis among test scores. This framework

5. The standard deviations are respectively 0.19 and 0.54; and the extent [-0.74;0.28] and [-2.19;1.87].

appears to represent a set of robust factors to explain economic decisions based on observation (and not experimentation). The two factors that we test here are conscientiousnes, which is degree to which a person is willing to comply with rules, and neuroticism (also called emotional stability), which is the degree to which a person see the world as dangerous (Costa and McCrae, 1992). These factors may affect the arrival and processing of the new information. Then, it is interesting to link the BFI factors to insurance premiums and information types. We can expect that people with a higher degree of conscientiousness and neuroticism will be more willing to buy and sell insurance.

In order to understand the effects of control variables, Table 4.9 reports the output of a regression. We can explain 20% of our insurance premiums with our control variables. As expected, the premiums are higher on the supply side and for HPLC events. Furthermore, the subjective probabilities (in both insurance and lottery context) and the certainty equivalent increase with the insurance premiums, enhancing a probabilistic formation of the willingness to pay and to accept, and the relationship between framings. The effect of risk aversion is positive and the effect of loss aversion is negative, as expected. Risk averse subjects tend to increase their premiums in order to avoid the risk while loss averse subjects decrease them as they link the payment of the premium to an immediate loss.

The results concerning the personality treats are less clear. Conscienciousness is not significant. Neuroticism has a negative impact while we could have expected that depressed subjects seeing the world as threatening will increase their premiums due to overestimation of the probabilities. However, nervous and tense people may not want to think about the future risks, while calm and stable people will think more thoughtfully about insurance choices[6]. The positive effect of the locus of control is more coherent: subjects with a need of control do not want to face the uncertainty of potential losses and prefer to avoid it by subscribing more insurance.

6. "Tense, Anxious, Nervous versus Stable, Calm, Contented" is the adjective check list of the neuroticism factor, see Costa and McCrae (1992).

Table 4.9: Impacts of control variables on the insurance premiums

Insurance premiums	*All questions*		*R1 and R3 excluded*	
	Coefficient	**Std. Err**	**Coefficient**	**Std. Err**
Subjective probability of insurance	0,058 ***	0,006	0,058 ***	0,008
Matching probability of lottery	0,051 **	0,021	0,040 *	0,021
Certainty equivalent of lottery	0,005 ***	0,005	0,039 ***	0,006
Risk aversion	0,354 ***	0,039	0,317 ***	0,043
Loss aversion	-0,038 ***	0,014	-0,035 **	0,015
Impatience	-0,000 **	0,000	-0,000 **	0,000
Neuroticism	-0,003 ***	0,001	-0,004 ***	0,001
Conscientiousness	0,000	0,001	0,000	0,001
Locus of Control	0,011 *	0,006	0,008 *	0,006
Insurance claim	0,182 ***	0,016	0,194 ***	0,016
Terrorism perception	0,026 **	0,014	0,021 *	0,014
Age	-0,002 *	0,001	-0,003 ***	0,001
Gender	0,082 ***	0,016	0,101 ***	0,017
Risk level (*HPLC vs LPHC*)	-0,167 ***	0,028	-0,176 ***	0,033
Market side (*D vs S*)	0,256 ***	0,025	0,275 ***	0,028
Contract *(Risk)*				
Imprecision	-0,026	0,020	0,041 *	0,026
Conflict	-0,037 *	0,020	0,030	0,026
Imprecise conflict	-0,012	0,020	0,055 **	0,026
Subcontract (*1*)				
2	-0,042 **	0,016	0,031 *	0,017
3	-0,018	0,017	0,079 ***	0,018
Constant	0,491 ***	0,076	0,466 ***	0,028
R-squared	0,200		0,211	

$*$ if $P \leqslant 0.1$, $**$ if $P \leqslant 0.05$, and $***$ if $P \leqslant 0.01$

Note: This table displays two regressions. The first column reports a regression on the all data-set with all questions. The second column reports a regression on the data-set excluding the responses to questions $R1$ and $R3$ that refers to risky situations that are not comparable with the other situations (see Figure 4.1).

One interesting result is the effect of past experience (the fact to have claim on insurance in the last three years) that increases the level of the willingness to pay and to accept. In this sense, "using" the insurance coverage allows to set higher insurance premiums, as the premium is not considered anymore as a simple "loss", insurance has been useful in the past. In addition, the terrorism perception is positively correlated with the insurance premiums, and can be seen as a proxy for pessimism (Chapter 2). Note that the usual control variables (as gender) has a significant effect.

The fixed effects of the contract type show a decrease in the insurance premium under ambiguity, which is linked to the risk information type because $R1$ and $R3$ are not comparable with the other situations. If we drop these variables, the results show a positive effect of ambiguity sources on the insurance premiums.

4.7 Conclusion

What is of particular interest here is whether the insurance decisions are fundamentally different for precise, imprecise and controversial events, on both the demand and the supply sides of the insurance market, and for both extreme and more likely events. We have built an incentivized experiment allowing to obtain complete information about insurance choices (prices, quantities, and beliefs).

Our results provide evidence that behaviors are different according to the information types. We come up with a ranking of insurance premiums across the information types ($\pi_R < \pi_I \leqslant \pi_C < \pi_{IC}$), that appears to be more significant for buyers than for sellers. The results also show that LPHC events are more underestimated than HPLC events, and that people are more willing to buy insurance for more likely events. Furthermore, demand and supply premiums are very different, the WTP being much lower than the WTA. The WTA-WTP gap is higher for extreme events, and is smaller under ambiguity. In addition, there are more purchasing and less selling under ambiguity than under risk, as subject on the demand side are more willing to buy insurance and subjects on the supply side are less willing to sell insurance. This means that when adding ambiguity, the price increases but the traded quantity is relatively stable. The possible exchanges are larger for HPLC than for LPHC events. Furthermore, framing effects are important across events, across contexts, and across question forms. Indeed, insurance results are larger than lottery results in terms of price but lower in terms of probability; and the gap between the price and probability results increases with the difficulty and the ambiguity of the situations. Finally, insurance decisions are strongly affected by risk attitudes, personality traits and past experience.

This experiment provides new evidence on the importance of the information type when taking insurance decisions. A main drawback is the difficulty of the experiment for standard subjects, especially on the supply side. It would be interesting to analyze the insurers' behaviors in a controlled experiment. Nevertheless, it opens the question of how insurance models could incorporate the behavioral responses facing precise, imprecise or conflicting information.

4.8 Appendix: Design of the experiment

1. **Control variables**
   - i Risk and loss aversions*
   - ii BFI (personality traits)*
   - iii Individual characteristics and past experience*
2. **Lottery choices**
   - i Elicitation of Certainty Equivalents (CE): *For each option, do you prefer playing the lottery or paying the price?*
   - ii Preference between two choices: *Which lottery do you rather want to play between the two?*
   - iii Elicitation of probability (Matching probability): *What probability do you consider as equivalent to the experts' opinion?*
3. **Insurance demand choices**
   - i WTP (BDM): *What is the maximal insurance premium that you are willing to pay to be covered against this risk?*
   - ii Subjective probability of event's realization*: *What probability do you consider as equivalent to the experts' opinion?*
   - iii Quantity of insurance contracts to purchase: *For each possible price, how many insurance contracts are you willing to buy, out of 100?*
4. **Break**
5. **Insurance supply choices**
   - i WTA (BDM): *What is the minimal insurance premium that you are willing to accept to cover this risk?*
   - ii Subjective probability of event's realization*: *What probability do you consider as equivalent to the experts' opinion?*
   - iii Quantity of insurance contracts to sell: *For each possible price, how many insurance contracts are you willing to sell, out of 100?*
6. **Payment**

Note: The steps marked with an asterisk (*) are the non-incentivized tasks.

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PART II

Analyses of the Market for Reinsurance

CHAPTER 5

The Market for Reinsurance: Description and Structure

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5.1 Introduction

Simply put, the reinsurance market is the insurance market for insurance companies. But in contrast to the primary insurance market, contractual arrangements in the reinsurance market are less standardized, more globalized and involve greater amounts of insured risks per contract. Of course, with this kind of risk transfer comes a premium that the primary insurer must pay to have the option to pass those losses on to the reinsurers. The "reinsurance industry", whereby primary insurers transfer financial responsibility of portfolios of insured exposure to reinsurance firms that operate on a global scale, is in fact a multi-billion dollar industry in terms of premiums, and an industry worth trillions of dollars in terms of the loss exposure. The gross written premiums of reinsurance amounted to about 186 billion dollars in 2005, and grew to 215 billion dollars in 2010 despite the financial crisis, which represents a growth of approximately 3% per year. In 2013, it is of 230 billion dollars. [1].

The main reason why insurers purchase reinsurance protection, and thus remove the financial responsibility of bearing the risk they accepted to assume in the first place, is to free the economic and risk capital that had to be put aside to eventually pay for losses that could arise. For many primary insurers, it is often more efficient to use this risk capital to induce an increase of their sales on the primary market, rather than keeping it in reserves to pay for future potential losses. Freeing economic and risk capital also allows the insurer to increase the quality of the service given to policyholders. Reinsurance allows a primary insurer to decrease his bankruptcy probability. This means that the policyholder rating and credit rating remain high, while at the same time, this decreases the cost of financing and increases the policyholders' willingness-to-pay for this product since he will feel more certain that money will be available when he comes to collect (see Zimmer *et al.*, 2012).

The economic importance of the reinsurance market transcends the pure insurer-to-reinsurer transaction. The health (or lack thereof) of the reinsurance market has non trivial repercussions on the primary market where firms and individuals seek to find a financial entity to which they would like to put the losses to which they are exposed.

1. Figures from FFSA and Sigma Swiss Re.

A case in point is that Berger *et al.* (1992), Born and Viscusi (2006) and Meier and Outreville (2006) have argued that shocks to the reinsurance market have a direct impact on the availability and pricing of primary insurance contracts. Furthermore, as we stated earlier, the reinsurance market is a way for primary insurers to raise capital at a lower cost than having to access capital markets directly (see Powell and Sommer, 2007, and Mayers and Smith, 1990) since the reinsurance market offers a potential for a premium reduction on the primary market. Being global in design and in economic contribution, and being solely populated by financially sophisticated players, one could argue that the reinsurance market is one of the most competitive financial markets in the world.

Despite the economic, social and political importance of the removed reinsurance market for the primary policyholder, the reinsurance market remains relatively complex and opaque in its structure, operations and competitiveness (Cummins and Trainar, 2009). This opacity is surprising given the number and the size of the transactions that occur each year, as well as the maturity of this centuries' old market (according to the Society of Actuaries, the first contract dates back to 1370, in Genoa, whereas the term itself appeared in Germany in 1658). In contrast, credit default swaps (CDS), which can almost be considered like insurance contracts since they pay out in the event of default by an obligor, are relatively young financial products containing much already available information. One of the possible reasons why the reinsurance market is so opaque is that the reinsurance market is essentially an over-the-counter financial market where the players' reputation and their capital requirements are important features. It is therefore not obvious that a primary insurer will reinsure with the reinsurer offering quotes at the lowest price, inasmuch as it is not automatic for a policyholder to go with the insurance company offering quotes at the lowest price. In other words, it is quite possible that the counter party risk in the insurance/reinsurance relationship is so great that participants will want to know and make sure that the reinsurer will be there, financially, in case his capital is needed.

Another reason that could explain the opacity of the reinsurance market is that the underlying risks are very different from one primary insurer to the next and from one market to the next. This means that even if two reinsurance programs share the same name for two primary insurers (or even for the same insurer, but in different geographical areas or in different time periods), the risk portfolios are not necessarily the same. Consequently, a reinsurer who is interested in covering the losses of a given portfolio of loss exposures needs to assess the actual risks (i.e. the distribution of losses in the region for which the reinsurer is financially responsible) that stem from such a program. In a sense, reinsurance contracts are more similar to collateralized debt obligations than to credit default swaps.

The goal of this paper is to examine the reinsurance market in a descriptive and global way in order to improve our understanding of its characteristics. The next section of the paper will review the main contributions of the empirical literature on the reinsurance market. Section 3 will present a primer on the reinsurance market to highlight its economic importance and the special terminology that is used by participants in that market. Specific features of the reinsurance market are presented in Section 5 from aggregate analyses of the market [2] in order to document and enhance the importance of this market.

5.2 Literature review

5.2.1 The market for reinsurance and its characteristics

The reinsurance market is complex and its structure is global. It also shows specificities that transcend any insurer-to-reinsurer relationship or single transaction. Compared to other over-the counter financial markets, the reinsurance market is particularly opaque, which has led Cummins and Trainar (2009) to judge this market difficult to examine and to study appropriately a fortiori. The foundations of reinsurance include the transfer, the diversification and the pooling of risks. In this sense, reinsurance decisions can be seen as a combination of three decision-making processes: risk sharing, risk management and financial structure.

Reinsurance contracts allow for the transferring of risks that insurers cannot or do not want to bear to more global actors. These contracts are based on the balance sheets of insurers, so that we can see their reinsurance decisions as depending on the amount of capital they hold since reinsurance is a way for insurers to reduce the amount of capital they

2. This analyses are made by big participants of the reinsurance market such as Swiss Re, Munich Re, SCOR, Guy Carpenter, FFSA...

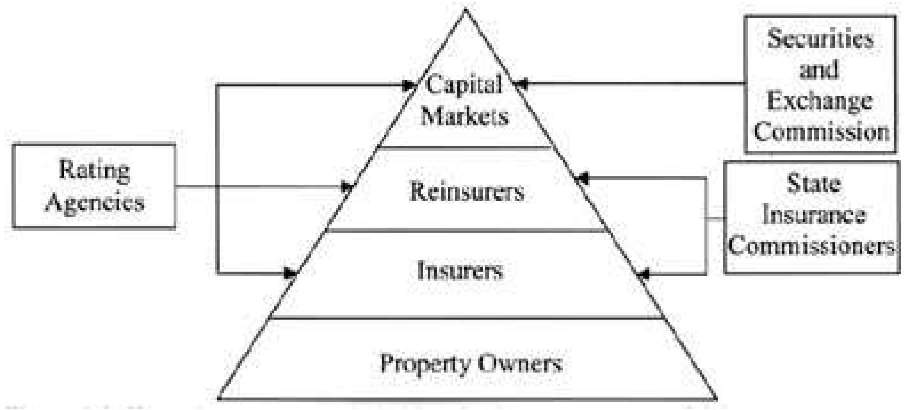

Figure 5.1: Key private sector stakeholders in the management of risk
Source: Grossi and Kunreuther (2005)

hold and to therefore increase their underwriting capacity. Reinsurance is also a way to reduce the volatility of losses and therefore to stabilize the primary insurer's financial result. Insurers and reinsurers can also use financial markets as a risk transfer tool (see Figure 5.1). In this sense and because of its ability to reach to the capital pool of global financial markets, the (re)insurance industry is well positioned to absorb large losses (Cummins et al., 2002). This is an essential feature of any insurance market when one is preoccupied by the well-being of policyholders. Moreover, capital adequacy of the insurance industry (that is, having enough capital to pay for the policyholders' losses) is one of the most important concerns of public policymakers and insurance regulators.

Irrespective of the reinsurance market's ability to access the global financial market, underwriting expertise remains the most central feature of any insurance transaction, whether it's the insurer's ability to assess a policyholder's risk type, or a reinsurer's ability to assess a primary insurer's risk portfolio. As the need for correctly assessing the risks that are involved is essential when dealing with reinsurance treaties, one is confronted with the Arrow (1971) question of the insurability. Succinctly, and using Grossi and Kunreuther's (2005) definition, we can define a risk as being insurable if it can be identified and quantified, even if both can only be partially done. Moreover, risk identification and quantification must lead to the setting of an insurance premium. An underwriter's challenge when dealing with complicated risks is that a significant level of uncertainty regarding the occurrence and level of future losses exists. This challenge is obviously much more important in the case of catastrophic events (Kunreuther and Michel-Kerjan, 2009), thus making an underwriter's job of risk assessment even more difficult. Even more so because it has been shown that insurers and reinsurers exhibit ambiguity aversion (Kunreuther et al, 1993). Consequently, and also because the insurance/reinsurance market is incomplete by construction, reinsurers must include a risk premium in their price schedule, just as investment bankers must include a risk premium when valuing financial derivatives when the underlying security is not traded (see Stentoft, 2004). Finally, the insurer's ceded premiums need to be accepted by the reinsurer in order for a market to exist (Shimpi, 1997).

Reinsurers possess a high technical expertise on risk assessment, which allows them to see through the opacity of insurers' book of business. They are able to analyze the risks insurers are willing to transfer in order to set a premium. It can be comparable with an audit of underwritten risks as well as an audit of the quality of the insurers' risk management strategy. This expertise occurs because of long and often repeated relationships between the reinsurer and the primary insurer, despite the fact that multiple-year contracts are non-standard in this market (see Jean-Baptiste and Santomero, 2000, and Boyer and Gobert, 2008). It naturally follows that reputation and trust among the participants are factors that are essential for the reinsurance market to function properly. That is perhaps one of the reasons why Plantin (2005) refers to reinsurers as "insiders", since they have more information about the risks than outside investors.

One last crucial aspect of the close relationship between a primary insurer and its reinsurer is that investors may view positively the presence of a reinsurer as a source of capital and protection, especially pertaining to the quality of the primary insurer's underwriting and management abilities. The reinsurer's presence may be seen as positive because reinsurers have an implicit monitoring role of the primary insurer's activities. This monitoring role reduces informational problems that could exist either internally, for the primary insurer, or with outside investors and potential policyholders (Jean-Baptiste and Santomero, 2000; Doherty and Smetters, 2002; Plantin, 2005). In that sense, the presence of a reinsurer could be compared to the monitoring role of credit rating agencies. Based on their experience, expertise and extensive presence on the global insurance market, reinsurers are able to provide risk management advice to primary insurers. Also, because they are directly involved with the risks they accept, reinsurers have a direct monetary incentive to design efficient contracts. For example, a line that is increasingly difficult to reinsure could indicate that the insurer is experiencing structural problems.

5.2.2 Reinsurance: from risk sharing to risk management decisions

The economic role and purpose of reinsurance can be studied alongside two important theoretical frameworks. The first one refers to the seminal work of Borch (1962), who considers reinsurance as a risk sharing decision among risk-averse agents. Borch (1962) uses an expected utility theory and a game theory approach to analyze the Pareto optimal amount of reinsurance. He predicts that each reinsurer should hold a proportional share of the market portfolio of reinsurance contracts; a concept similar to the Capital Asset Pricing Model of Sharpe (1964) and Lintner (1965). This means that losses will be correlated among reinsurers. Following Borch's theorem, Doherty and Smetters (2005) and Zhang and Siu (2009) have made further advances in order to include behaviors such as ambiguity aversion and moral hazard in the optimal reinsurance portfolio decision process. Unfortunately, predictions associated with the risk sharing approach do not seem to comply with actual reinsurance decisions (see Froot, 2001). We can therefore conclude that as much as risk sharing is a very appealing reason for the existence of a reinsurance market, it is in no way sufficient to explain the primary insurers' decision to reinsure their exposure.

The second theoretical framework along which the role of reinsurance has been studied by insurance economists is to consider reinsurance as a corporate risk management tool. The seminal paper of Mayers and Smith (1990) studies the determinants of reinsurance purchases by property and casualty insurance companies. They equate the demand for reinsurance to the demand for risk management by any non-financial firm. They demonstrate that the ownership structure matters in the reinsurance decisions so that more ownership-concentrated firms purchase more reinsurance. Moreover, subsidiaries and group members reinsure more. Furthermore, insurer size and default risk are highly correlated with the demand for reinsurance. Firms that are less diversified across lines-of business or geographically are found to purchase less reinsurance, which contradicts the theoretical results of

Borch (1962). However, the fact that geographic and business concentrations decrease the demand for reinsurance can be explained by the technical expertise and the monitoring role that reinsurers play in the economy (Plantin, 2005).

To cover all possible insurance claims (Merton and Perold, 1993), an insurance company's balance sheet is composed of both internal risk capital (such as equity and bond investors) and external risk capital (such as reinsurance contracts). Given that Zanjani (2002) has shown that capital costs are an important component of reinsurance pricing, it follows that the benefits of reinsurance depend on the relative costs of each type of risk capital. Culp and O'Donnell (2009) explain that the external risk capital is often less expensive than internal one, even if it does not seem as such, in the sense that it provides insurance companies with cash to cover policy claims ex ante and it is more transparent. Powell and Sommer (2007) propose that the opposite is more likely to be true because of the important presence of information asymmetry and agency costs in the insurer's main area of operations. Information asymmetries are indeed important considerations when looking at insurance arrangements. Agency theory brings to light ethical problems and adverse selection that are very much studied in the insurance and reinsurance markets (Cummins and Tennyson, 1996; Chiappori and Salanié, 2000; Abbring, Pinquet and Chiappori, 2003; Dionne, Michaud and Dahchour, 2004; Doherty and Smetters, 2005). According to Fazzari et al. (1988), the cost of capital depends on the amount of asymmetry between providers and users of capital. Having a long term relationship with a reinsurer can make the reinsurance premiums decrease. These long term relationships do not need to be codified in multiple year contracts, but can result from repeated contracts over the years. In this way, the information is revealed over time and, after a number of trades, the reinsurance contract gets closer to the optimum (Jean Baptiste and Santomero, 2000; Boyer and Gobert, 2008).

Insurers, and reinsurers for the great majority of them, use financial markets in order to raise capital. According to Sommer (1992) and Mayers and Smith (1990), reinsurance is less costly than capital markets. However, securitization can be considered as a complement to reinsurance according to Cummins and Trainar (2008). Indeed, Cat Bonds are an interesting tool that hedge catastrophic risks in decreasing default risk of reinsurers (replaced by basis risk), moral hazard, and reinsurance prices (Lee and Yu, 2007). However, they have not been very successful in the industry. The regulatory requirements stating a capacity level for insurance companies do not include securitization in the insurer' balance sheet, or with limits, which explains the relatively low attractiveness of Cat Bonds for insurers (Han and Lai, 1997). Securitization and reinsurance do not have the same economic function: securitization appears as an intermediation tool, while reinsurance is better explained as also being a warehousing of risk (Cummins et al, 2008; Cummins and Trainar, 2009).

In particular, Cummins et al. (2008) re-examine the determinants of reinsurance, and offer a new explanation to Froot's (2001) findings whereby reinsurance premiums appear much higher than their actuarially fair price. The results in Cummins et al. (2008) suggest that reinsurance premiums are not only explained by the underwritten risk, but also by the amount of capital needed and by informational problems (i.e. agency costs) that plague the insurer/reinsurer relationship. Furthermore, less experienced insurers are willing to pay higher premiums in order to gain access to the reinsurers' technical expertise. And although it is found that reinsurance is indeed quite costly for insurers, it still remains a very useful device since it reduces the primary insurer's loss ratio volatility, and it increases his underwriting capacity. This means that purchasing an appropriate amount of reinsurance diminishes the default risk of the primary insurers since it protects them against extreme events. That is possibly why Garven and Lamm-Tennant (2003) found that insurers with high financial leverage demand more reinsurance.

Another challenge that primary insurers are faced with is reinsurer's credit risk. Indeed, insurers should want to diversify their protection against extreme events across reinsurers in order to mutualize the default risk of the reinsurers. The implication of such a need for high credit-worthy reinsurers is that insolvency-averse (i.e. risk-averse) primary insurers are willing to pay a higher premium for a contract that is underwritten by a low default-risk reinsurer (Sommer, 1996). Reinsurers diversify their risks by reinsuring risks from all over the world and from different lines of business, which Cummins and Trainar (2009) attribute to the fact that reinsurance is optimal when dealing with independent and uncorrelated risks. The law of large numbers does not hold true, however, for extreme and correlated events like natural catastrophes. For extreme events, the cost of capital can become very expensive and the reinsurance premium very high (see, for instance, Ibragimov et al., 2009, Ibragimov and Walden, 2007, and Boyer and Nyce, 2012). Insurance securitization (see Cummins and Trainar, 2009, and Albertini and Barrieu, 2009) is needed to transfer correlated high-consequences events. Lane (2000) states that both reinsurance premiums and Cat Bond prices should be related to credit prices (such as corporate bonds) because these assets contain the assessment of the frequency and the severity of risks.

With the recent financial crisis, reinsurance premiums increased and insurance capacity decreased drastically (Culp and O'Donnell, 2009). As for the liability crisis of the mid-1980s (Berger et al., 1992), one can see the recent trends in reinsurance prices and capacity as the result of a large negative shock on reinsurance supply and as a positive shock on reinsurance demand (see Figure 5.2). These trends are similar to what can be observed after a large claim event. The difference with the recent credit crisis is that it also became a financial system confidence crisis. In that case, reinsurers became reluctant to offer capital, by fear it would affect their reputation of reinsuring primary insurers that were on the brink of bankruptcy (and thus perhaps betting for resurrection by accepting to underwrite and insure riskier clients). And as the cost to reinsure increased during the confidence crisis, reinsurance premiums rose. The trickled down impact to the primary insurance market was an increase in premiums either because the primary insurers had to pay more for their reinsurance protection, or because the primary insurer could not find any reinsurer willing to accept his business, thus raising the primary insurer's cost of bearing risk. Berger et al. (1992), Born and Viscusi (2006) and Meier and Outreville (2006) present convincing evidence which shows that shocks to the reinsurance market can have a direct impact on the availability and pricing of primary insurance contracts. In a similar fashion, Myers and Majluf (1984) argue that suboptimal reinsurance coverage can lead to higher premiums for the consumers.

5.2.3 Tranching and pooling in reinsurance

As highlighted in Boyer and Nyce (2012), reinsurance contracts are often subdivided into tranches that allow reinsurers to obtain an exposure whereby the maximum possible

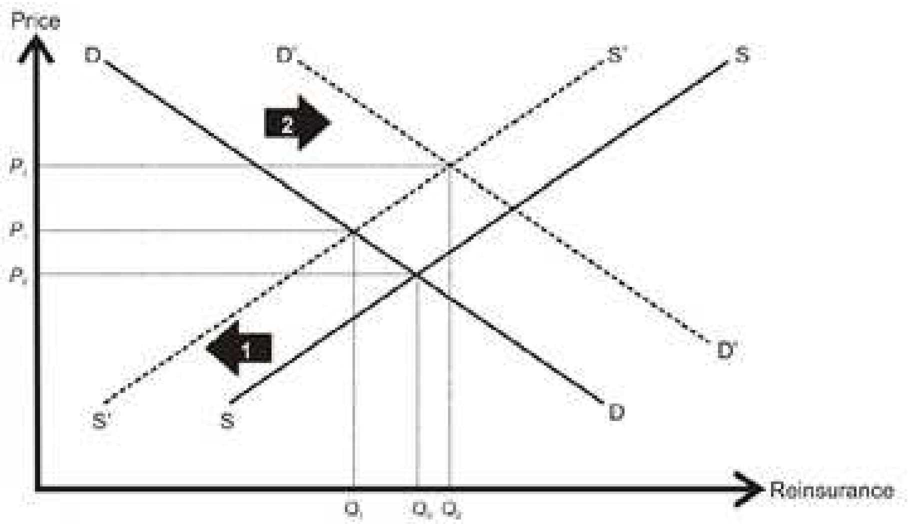

Figure 5.2: Reinsurance pricing and the credit crisis
Source: Culp and O'Donnell (2009)

loss is well-defined. That is one of the reasons why non proportional reinsurance contracts are the most common types of contracts between an insurer and a reinsurer. This means that reinsurance contracts are sold in layers, also known as tranches (Hurlimann, 2003; Plantin, 2003; Ladoucette and Teugels, 2006). Furthermore, most prudential regulations reduce the reinsurance purchases from the minimum capital requirement (Plantin, 2005).

Tranches of reinsurance contracts can be regarded as financial agreements akin to tranches of collateralized debt obligations (CDO). The similarities between CDO tranches and reinsurance tranches were made clear in Plantin (2003) who analyzed the tranching of reinsurance in comparison to CDO layers. CDO tranches are split into several tranches with specific seniorities (from rated notes to un-rated notes, also called the equity tranche or the toxic waste tranche). CDO buyers can have various levels of risk sophistication (i.e. their ability to assess the obligor's credit risk varies) and various degrees of willingness to be exposed to credit risk. It appears that more risk-sophisticated institutions buy tranches with low seniority because they are better able to properly assess the risk involved, so that more senior tranches are either retained by the CDO originator or purchased by more risk-averse or less sophisticated institutions. The reason why Plantin (2003) is able to draw an intelligent comparison between tranching in reinsurance and in CDO is that primary insurers, like CDO originators, sell their claims in layers to reinsurers on the reinsurance market. The layering of reinsurance contracts (see Figure 5.3) is designed so that the primary insurer bears the first losses up to a retention (first priority level), which plays the same role as the equity tranche in CDO. This first retention level is structured similarly to a deductible in order to decrease transaction costs and the cost associated with moral hazard. Reinsurers assume the risk of the superior layers, as represented as layers 1 through layer 5 in Figure 5.3. Once all layers have been exhausted, it is the insurer's shareholders turn to assume the excess losses up to the total value of the firm's equity. If the losses are larger than the sum of all the reinsured layers and of the primary insurer's capital, then the remaining losses will be borne by the policyholders themselves since the insurer will be in a state of technical bankruptcy. As an alternative to letting the policyholders assume losses in those higher tranches, local, national and supranational governments can choose to step in as the last resort reinsurer (see Kessler, 2008; Michel-Kerjan and Wise, 2011; and Boyer and Nyce, 2013).

Due to their long-time expertise, experience and worldwide risk pooling, more sophisticated reinsurers have typically accepted to bear the risk of losses in first layers. According to Plantin (2005), tranching is a way to simultaneously appeal to sophisticated and informed investors, and to comfort unsophisticated and uninformed ones (also see Gorton and Pennacchi, 1990; and Boot and Thakor, 1993). This then raises the question of why and when should tranching be present.

According to Axelson (1999, 2007), the pooling of assets is efficient if there are a large number of individual assets compared to the number of potential investors, so that each investor is then responsible for a proportion of all losses. This reduces the potential for adverse selection problems. In comparison, if there are a great number of potential investors, then tranching is optimal. According to De Marzo (2005), tranching is efficient if the issuer (i.e. the primary insurer in the insurance/reinsurance market) has superior information about the value of its assets (i.e. the pool of risks). Furthermore, if the risks are not highly correlated, using layers allows for the risk diversification while it also preserves the information structure. However, if the issuer cannot precisely assess his risks, pooling

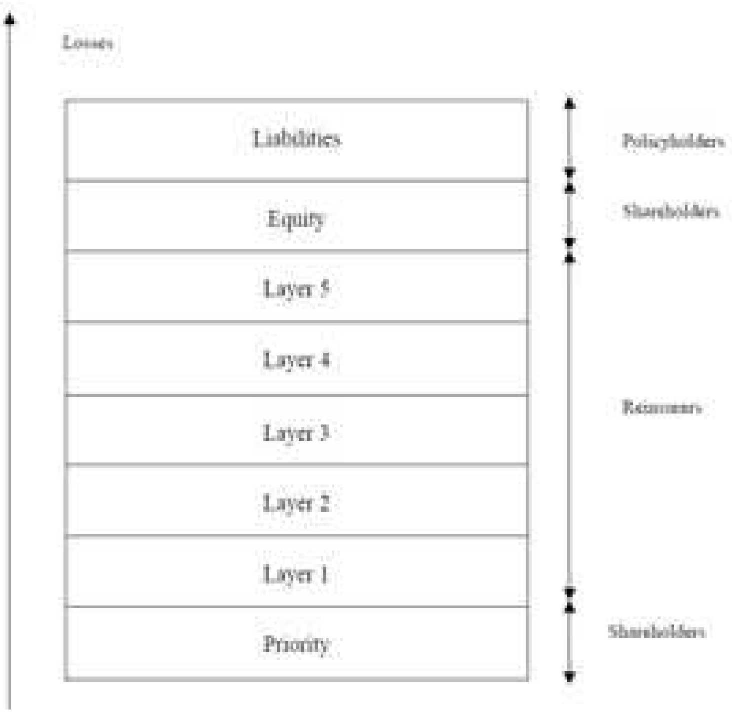

Figure 5.3: Non proportional reinsurance
Source: Plantin (2003)

prevents the better informed investors (in this case, the reinsurers) from selecting the best layers. The consequence of this dynamic is that the equilibrium between pooling and/or tranching depends essentially on the distribution of private information in the market and on the difference in the different players' information. Moreover, if tranching is done properly, Brennan et al. (2009) have shown that tranching can create marketing gains, and that these gains increase in the number of tranches. A case in point is the study of Cuchra and Jenkinson (2005). They analyzed the number of tranches in European bond securities and found that assets with high information asymmetry tend to have more tranches with different ratings.

No doubt that an important level of information asymmetry exists and that each reinsurance market actor uses his own risk assessment model in order to either determine the minimum reinsurance premium against which a reinsurer is willing to assume the risk, or to determine the maximum reinsurance premium that the primary insurer is willing to pay to get rid of the liability. Of course, models differ depending on the reinsurer. They depend, among other things, on the pool of risks for which the reinsurer is already responsible and on the reinsurer's proprietary underwriting technology. This heterogeneity across insurers can, of course, lead to very heterogeneous prices. The situation that is observed on the reinsurance market is not much different than the situation on the mortgage-backed securities auction market. Bernardo and Cornell (1997) find highly variable bids on the mortgage-backed securities auctions market as the winning bid exceeds the median bid by an average of over 17%.

The transposition of the results found in capital markets to the reinsurance industry is not trivial. Nevertheless, Biffis and Blake (2010) examine the securitization and tranching of longevity risks under asymmetric information using a signaling model. In a model where insurers and reinsurers are risk assessment experts in comparison to uninformed regular investors, they demonstrate that retention levels and the securitization of risks allow for a reduction on the impact of asymmetric information (see also Cowley and Cummins, 2005). One can then presume that there are important benefits to tranching and pooling, which means that the basic structure of the reinsurance market should reflect these specificities.

5.3 A primer on the reinsurance market

The global reinsurance market is populated by important players which are large financial institutions. That is perhaps the most important specificity of that market. There is also a vocabulary that is specific to the reinsurance market that has not translated to capital markets for any number of reasons. The contract between a primary insurance company and a reinsurer is called a reinsurance treaty. This treaty is purchased by a primary insurer (also referred to as "the ceding company") to a specialized reinsurance company or to another insurance company. The type of reinsurance contract is also specific to the type of risk that the primary insurer is trying to reinsure. There are two forms of reinsurance treaty: proportional and non-proportional. We focus here on the second form. In particular, property and casualty reinsurance contracts generally take the form of excess-of-loss treaty. In such a contract, the reinsurer is responsible for losses that are in excess of some amount (referred to as the "priority") up until some other amount (referred to as the "limit"). A reinsurance layer is therefore defined as a limit exceeding a priority (written "limit XS priority"). Of course, and following the previous discussion, a reinsurance treaty can have several layers on top of each other, as well as layers that are parallel to each other (see Boyer and Nyce, 2012, for an industrial organization model of the reinsurance market).

In terms of notation, an "excess of loss" treaty will take the form of $L\,XS\,P$. This means that the potential liability for the reinsurer has the following function : $Min[Max(x-P;0);L]$. Financial economists will recognize this payoff function as a bull spread on underlying security x, in which the derivative instrument pays off when $x \in [P, P+L]$. One may then say that the reinsurer is "short the bull spread" since it needs to pay out an amount equal to $x-P$ if the underlying security is worth more than P, up to a maximum of L. As we know, being short a bull spread is similar to having sold a call option with a strike price P, and purchasing a call option with strike price $P+L$. In the reinsurance market, the terms used are slightly different than in the financial derivatives market. We will then have:

- x is the loss associated with an unfortunate event (similar to the concept of loss given default in fixed income security analysis),
- P is the priority,
- L is the limit;
- $L+P$ is the ceiling of the treaty.

The reinsurer intervenes if the event's loss is superior to P. The reinsurer then pays out the primary insurer for all losses greater than P, subject to a deductible equal to P. The maximum the reinsurer can be liable for is L. Thus, the term L XS P means that the reinsurer pays no more than L on the part of the cost that exceeds P. If the total cost of an event exceeds $L+P$, then it is no longer that reinsurer's responsibility, as the liability falls back to the primary insurer, unless of course the primary insurer found another reinsurer to cover the losses greater than $L+P$. 's will be responsible for the exceeding losses [3].

3. For the insurer, the payoff is akin to having purchased a call option with exercise price P on the losses due to the event, and selling a call option with exercise price $L+P$ on the same losses.

In practice, a reinsurance treaty is split into different layers. For example, a treaty 200 XS 20 can be split into four layers: 10 XS 20, 20 XS 30, 100 XS 50 and 70 XS 150. Separating the total liability into distinct tranches increases the attractiveness of the entire contract since it allows each reinsurer to choose the degree of volatility and exposure to the primary insurer's book of business. It also reduces each reinsurer's risk since they are only responsible for the part of the loss within the layer, and it encourages competition between reinsurers. By bidding more or less for every layer, the reinsurer can find himself with a level of risk that is commensurate with what he wants. Similar to financial securities, the highest layers are the most "uncertain" layers since they concern the distribution tails, akin to the fact that the more out-of-the-money the options are, the more volatile their price before maturity. The lowest layers[4] are more often hit, and therefore are the most risky. The layers' price should then decrease over the layers, but be more volatile.

Two indicators are generally used to characterize the cost of a reinsurance layer: The rate-on-line (RoL), and the pay-back, as follows:

$$RoL = \frac{Reinsurance\ Premium}{Limit} = \frac{1}{PayBack}$$

Each indicator's role is to define a measure per unit of risk assumed by the reinsurer. In the case of the rate-on-line, we have a measure of the premium that the reinsurer receives per unit of risk he is assuming. The pay-back is an amortization period, which we can see as the number of years of premium that a reinsurer must collect to finance the payment of the entire layer (or the reinsurer's payment capacity). The layers can be classified according to their RoL and to their pay-back (see Table 5.1). Working layers are the ones, with high rate-on-line and quick amortization (i.e. it only takes 6 years to accumulate enough premiums to guarantee the capacity of that layer) and are intended to be used very often - thus the use of the term: “Working layers”. Catastrophic layers, on the other hand, are rarely used or affected by losses since they are designed to cover against infrequent catastrophic events. Using the $PayBack$ measure, we can say that a catastrophe is designed as such if a loss occurs less frequently than once every 25 years.

4. The lowest layers are usually used to smooth the loss ratio, while the highest layers prevent extreme losses.

Table 5.1: Classification according to the Rate-on-Line and Pay-Back

	Rate-on-Line	Pay-back
Working layers	> 15	< 6.5 years
Middle layers	from 4 to 15	from 6.5 to 25 years
Cat. layers	< 4	> 25 years

Source: Deelstra and Plantin (2005)

An insurance company willing to buy reinsurance can request quotes from different reinsurers for each layer of the reinsurance treaty. In the great majority of cases, those requests are made through an intermediary called a reinsurance broker. Unlike in the securitization market, where investors can be almost any type of institution or individual seeking a particular exposure to the risk that is being securitized, the reinsurance market mostly includes specialized firms whose sole purpose is to sell protection to primary insurers for their exposure portfolio. The opacity of the insurance market (i.e. not everything is known by all participants regarding the potential loss that insurers may suffer) requires that reinsurers have a specific knowledge of the types of risks they are willing to underwrite and assume. Reinsurers will sometimes be in a better position than the primary insurers, in the sense that reinsurers often have a better understanding of the qualitative and quantitative nature of the risk that the insurer has accepted to underwrite and assume. This is especially true in the case of highly technical risks.

There are typically two types of excess of loss reinsurance treaties: the treaties are either risk based or event based. The reason why these two types of contracts co-exist is that they offer the reinsurer and the insurer some flexibility with regards to the exposure that one wants to acquire and that the other wants to divest.

i. Treaty by risk: Exposure is linked to a possible event to a single risk (or contract) in the insurer's portfolio. The risk is usually associated with a single policy, a single insured or a single umbrella insurance policy.

ii. Treaty by event: Exposure is connected to the emergence of an event (natural catastrophe, technological accident,...), affecting several risks that are known to be partially correlated, such as several policies in a given geographical area, or several policies for a given age group. In that case the reinsurer is exposed to an accumulation of disasters. [5]

The type of risk that is being insured also plays an important role since not all lines of business (the term "line of insurance" is also often used to identify the lines of business in which an insurer is involved) have the same statistical distribution. This means that it is of prime importance to distinguish which lines of insurance are being ceded and reinsured, in any data-set. Lines of business that require more technical know-how and more knowledge will be more expensive to reinsure; not all lines of business can be compared directly. Moreover, the events that can affect lines of insurance are different depending on the risk that is insured.

In terms of reinsurance pricing, several methods are used by players in the reinsurance market. These pricing methods are known as: Experience pricing, Probability pricing and Exposure pricing. The pricing methods are quickly detailed below:

- Pricing on experience (burning cost) takes into account the past claim of the portfolio over several years, which is discounted to fit the current exposure.
- Probability pricing consists in determining a frequency-severity model and running simulations.
- Pricing on exposure uses the information available on the portfolio and the exposure to estimate which part of the bonus returns to the reinsurer.

Finally, an important characteristic of most reinsurance treaties is the reinsurers' annual maximum capital commitment, irrespective of the number of events that may plague a given treaty on a given risk and exposure. In practice, this total commitment is expressed in multiples of the limit for a single event or exposure and is called the number of recoveries. Thus, a treaty "20 XS 10" with two recoveries implies that the annual maximum

5. Treaties by conflagration also exist, but they are more difficult to appraise and will not be analyzed in the present document.

commitment of the reinsurers is limited to 60 million. The premium initially paid by the insurer only corresponds to a commitment equal to one limit. As events happen and use up the limit, the insurer has the obligation of paying an additional premium, called a re-instatement premium, in order to have the reinsurance contract reinstated to cover losses due to any new event that the primary insurer remains exposed to, for the same portfolio of risks.

The reinsurance market can be represented by an auction market. Indeed, the primary insurer willing to acquire reinsurance protection usually requests reinsurance quotes from many different reinsurers for each layers of a given reinsurance treaty. This allows the cedent to have an idea of the market price and to choose more efficiently who will be leader on the tranche or treaty. The cedent chooses the leader after receiving all the different reinsurer quotes. She can decide to have the same leader for the entire treaty or different leaders for each tranche of the treaty. The leader will be responsible for the largest proportion of the layer, and its quoted price (after some further negotiations between the cedent and the lead reinsurer) will have to be accepted by all chosen reinsurers that are willing to have part of the auction. The ceding company is the one dividing the layer between the interested reinsurers. This means that the name of leading reinsurer has to be made public in order for other reinsurers to follow its lead. In the end, several reinsurers, generally a sub-sample of those who bid in the first place, will be responsible for losses in a given tranche of a reinsurance treaty, but not necessarily each in the same proportion, the leader being responsible for the largest proportion.

5.4 General figures and conclusion

One important things to recall is that all losses from catastrophic events are not fully (re)insured. We can see in Figure 5.4 in Appendix that even if the reinsurance market is a global and sustained market, there is a huge gap between the economic losses and the (re)insured ones. The economic losses were of 528 billion dollars between 1981 and 1990, 1,200 between 1991 and 2000, and 1600 between 2001 and 2011 (Munich Re, 2012). The scale of (re)insured loss radically changed with hurricane Andrew of 1992 which cost more than 26 billion dollars, and the Northridge earthquake of 1994 with its 22 billion dollars losses. This is linked to a problem of under-insurance. The costliest event of all occurred in Japan in 2011 with an earthquake, a tsunami and a nuclear catastrophe. Kunreuther and Michel-Kerjan (2011) explain the growth of catastrophe events with the growth of the population in exposed regions, the growth of economic value on these regions, the environmental destruction of the natural habitat, and the impact of climate change.

The tables in Figure 5.6 in Appendix show the huge difference between the ten costliest events worldwide in terms of economic losses, in terms of insured losses and in terms of human losses. We can note that, out of 10, 7 to 8 events occurred since 2001. Most of the costliest events in terms of insured losses are the United States due to hurricanes. The only European event of the list is the 2003 heat wave with 70,000 fatalities. 20% of the insurance costliest events, 50% of the economic costliest events, and 80% of the deadliest events occurred in developing countries, which shows that (re)insurance markets are not well developed in these countries.

Furthermore, the worldwide amount of insurance gross written premiums is about 4,613 billion dollars in 2012, while the amount of reinsurance premiums is about 230 billion of dollars. Figure 5.5 displays the evolution of the insurance and reinsurance premiums and of the global GDP. The GDP and the insurance written premiums increased respectively of 148% and 149%, while the reinsurance market only increased of 92%. As Froot (2001) says, insurance companies tend to retain their low probability risks, and they prefer share medium and small size risks on the reinsurance market.

In looking closely at the reinsurance prices of catastrophe events, the main risk coverage of reinsurance, Figures 5.7 and 5.8 in Appendix display the global catastrophe Rate-on-Line, that we can put in perspective with the previous major events. In 2005, Katrina, Rita and Wilma hit North America. The season is an unprecedent and most active Atlantic hurricane season in recorded history, which increased claims for reinsurers of about 50 billion dollars, compared to a yearly insurance premium of 180 billion dollars all risks put together. Only one reinsurer went bankrupt, which records of the strength of the reinsurance market, of the fact that reinsurers assess relatively correctly the risks and know their core of business. The subprime crisis cost 600 billion dollars to the reinsurance market, a relative small cost compared to the real estate market in the US (11,000 billion dollars), but that was still a big disruption in the reinsurance market.[6] Furthermore, we can clearly see on Figures 5.8 that these shocks impacted more violently the United States than the rest of the world.

Froot (2001) finds that reinsurance premiums are more than seven times higher than the expected loss (from 198 to 1998), with an increase of the premium-to-expected-loss (due to Katrina), and then a fall. He explains why the reinsurance premiums are so high and the traded quantity quite low and raises 8 explanations. Most of them focus on distortions on the supply side of the reinsurance market such as the insufficient capital, the reinsurers' market power, the opacity of the market, the high frictional costs, and the effects of moral hazard and adverse selection. In addition, problems on the demand side of the reinsurance market are the government ex-post intervention, agency issues, and behaviors factors of managers.

This chapter has presented the reinsurance industry through the empirical literature, a primer of the reinsurance jargon, and global figures of the market. This descriptive analysis displays interesting features of the reinsurance contracts and of the global reinsurance market. Given these features, further research is needed for in-depth analyses about the explanatory factors of reinsurance demand and supply. To do so, we were given access to a unique and proprietary data-set on non-proportional reinsurance treaties that allows us to examine and analyze the structure of the treaty and of the reinsurance prices. The data-set spans six years (2005 through 2010) and contains the quotes for different reinsurance layers, different clients, different treaties and different lines of business. We are going to analyze the specific factors of reinsurance prices in the next chapter.

6. Figures from SCOR

5.5 Appendix

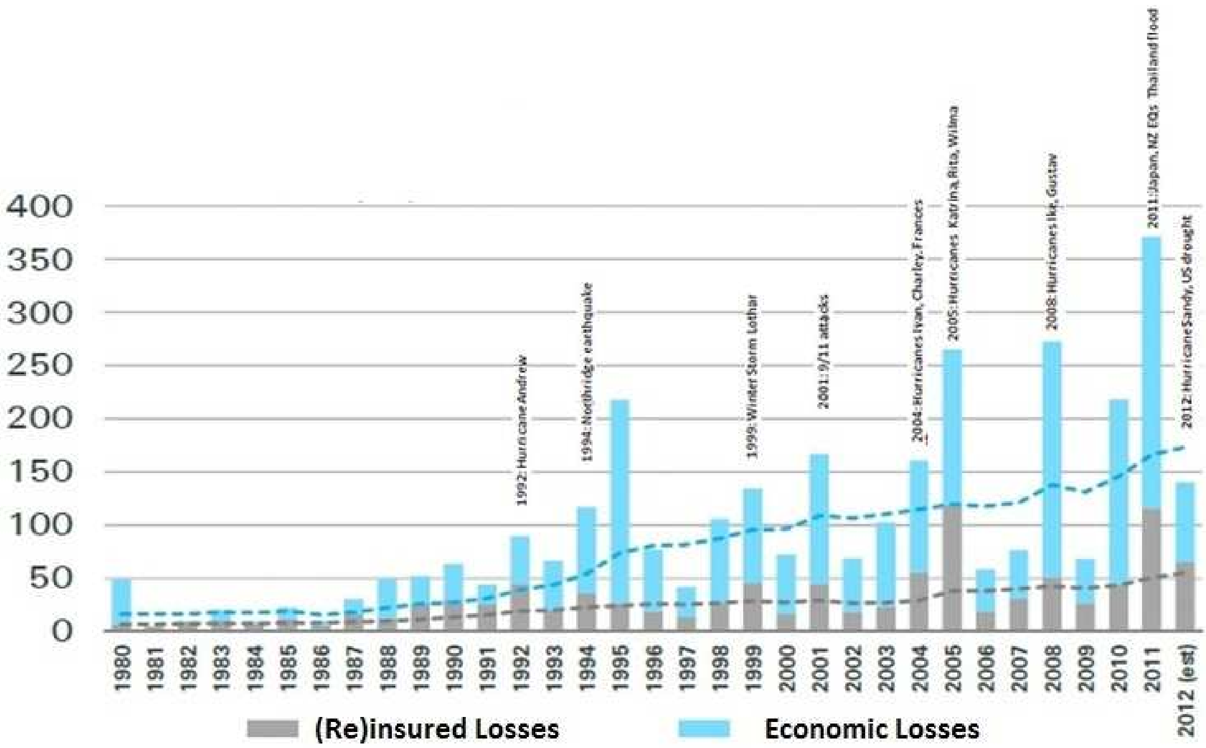

Figure 5.4: Gap between the economic and (re)insured losses (in 2012 bn$)
Source: Swiss Re, Sigma

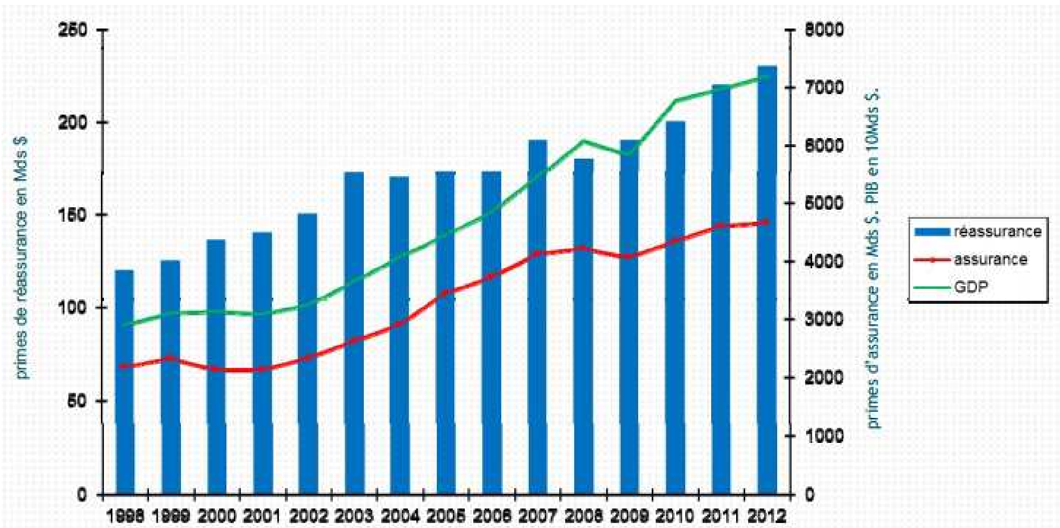

Figure 5.5: Worldwide gross written premiums of the (re)insurance markets from 1998 to 2012 (in USD billion)
Source: SCOR, S&P GRH, IAIS, Sigma

10 costliest events worldwide ordered by overall losses

Period	Event	Affected Area	Overall losses	Insured losses	Fatalities
			US$ m, original values		
11.3.2011	Earthquake, tsunami	Japan: Honshu, Aomori, Tohoku; Miyagi, Sendai; Fukushima, Mito; Ibaraki; Tochigi, Utsunomiya	210,000	40,000	15,840
25-30.8.2005	Hurricane Katrina, storm surge	USA: LA, New Orleans, Slidell; MS, Biloxi, Pascagoula, Waveland, Gulfport	125,000	62,200	1,322
17.1.1995	Earthquake	Japan: Hyogo, Kobe, Osaka, Kyoto	100,000	3,000	6,430
12.5.2008	Earthquake	China: Sichuan, Mianyang, Beichuan, Wenchuan, Shifang, Chengdu, Guangyuan, Ngawa, Ya'an	85,000	300	84,000
24-31.10.2012	Hurricane Sandy, storm surge	Bahamas, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, USA, Canada	65,000	30,000	210
17.1.1994	Earthquake	USA: CA, Northridge, Los Angeles, San Fernando Valley, Ventura, Orange	44,000	15,300	61
1.8-15.11.2011	Floods	Thailand: Phichit, Nakhon Sawan, Phra Nakhon Si Ayuttaya, Pathumthani, Nonthaburi, Bangkok	43,000	16,000	813
6-14.9.2008	Hurricane Ike	Cuba, Haiti, Dominican Republic, Turks and Caicos Islands, Bahamas, USA	38,000	18,500	170
May - Sept 1998	Floods	China: Jangtsekiang, Songhua Jiang	30,700	1,000	4,159
27.2.2010	Earthquake, tsunami	Chile: Bió Bió, Concepción, Talcahuano, Coronel, Dichato, Chillán; Del Maule, Talca, Curicó	30,000	8,000	520

10 costliest events worldwide ordered by insured losses

Period	Event	Affected Area	Overall losses	Insured losses	Fatalities
			US$ m, original values		
25-30.8.2005	Hurricane Katrina, storm surge	USA: LA, New Orleans, Slidell; MS, Biloxi, Pascagoula, Waveland, Gulfport	125,000	62,200	1,322
11.3.2011	Earthquake, tsunami	Japan: Honshu, Aomori, Tohoku; Miyagi, Sendai; Fukushima, Mito; Ibaraki; Tochigi, Utsunomiya	210,000	40,000	15,840
24-31.10.2012	Hurricane Sandy, storm surge	Bahamas, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, USA, Canada	65,000	30,000	210
6-14.9.2008	Hurricane Ike	USA, Cuba, Haiti, Dominican Republic, Turks and Caicos Islands, Bahamas	38,000	18,500	170
23-27.8.1992	Hurricane Andrew	USA: FL, Homestead; LA; Bahamas	26,500	17,000	62
1.8-15.11.2011	Floods	Thailand: Phichit, Nakhon Sawan, Phra Nakhon Si Ayuttaya, Pathumthani, Nonthaburi, Bangkok	43,000	16,000	813
June - Sept 2012	Drought, heat wave	USA: Midwest	20,000	15,000-17,000	100
17.1.1994	Earthquake	USA: CA, Northridge, Los Angeles, San Fernando Valley, Ventura, Orange	44,000	15,300	61
7-21.9.2004	Hurricane Ivan	USA, Caribbean, Venezuela, Colombia, Mexico	23,000	13,800	120
22.2.2011	Earthquake	New Zealand: South Island, Canterbury, Christchurch, Lyttelton	16,000	13,000	185

10 deadliest worldwide events

Period	Event	Affected Area	Overall losses	Insured losses	Fatalities
			US$ m, original values		
12.1.2010	Earthquake	Haiti: Port-au-Prince, Petionville, Jacmel, Carrefour, Leogane, Petit Goave, Gressier	8,000	200	222,570
26.12.2004	Earthquake, tsunami	Sri Lanka, Indonesia, Thailand, India, Bangladesh, Myanmar, Maldives, Malaysia	11,200	1,000	220,000
2-5.5.2008	Cyclone Nargis, storm surge	Myanmar: Ayeyawaddy, Yangon, Bugalay, Rangun, Irrawaddy, Bago, Karen, Mon, Laputta, Haing Kyi	4,000		140,000
29-30.4.1991	Tropical cyclone, storm surge	Bangladesh: Gulf of Bengal, Cox's Bazar, Chittagong, Bola, Noakhali districts, esp. Kutubdia	3,000	100	139,000
8.10.2005	Earthquake	Pakistan, India, Afghanistan	5,200	5	88,000
12.5.2008	Earthquake	China: Sichuan, Mianyang, Beichuan, Wenchuan, Shifang, Chengdu, Guangyuan, Ngawa, Ya'an	85,000	300	84,000
July - Aug 2003	Heat wave, drought	France, Germany, Italy, Portugal, Romania, Spain, United Kingdom	13,800	1,120	70,000
July - Sept 2010	Heat wave	Russian Federation: Moscow region, Kolomna, Mokhovoye	400		56,000
20.6.1990	Earthquake	Iran: Caspian Sea, Gilan province, Manjil, Rudbar; Zanjan, Safid, Qazvin	7,100	100	40,000
26.12.2003	Earthquake	Iran: Bam	500	19	26,200

Figure 5.6: Significant natural catastrophes from 1980 to 2012
Source: Munich Re, Münchener Rückversicherungs-Gesellschaft, Geo Risks Research, NatCatSERVICE

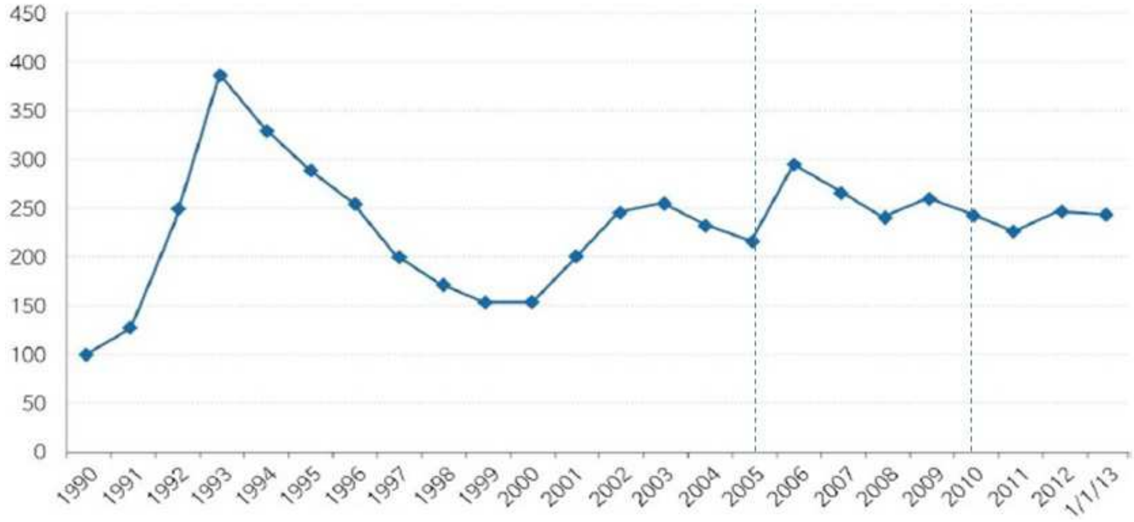

Figure 5.7: Global property catastrophe RoL Index from 1990 to 2013
Source: Guy Carpenter & Company, LLC

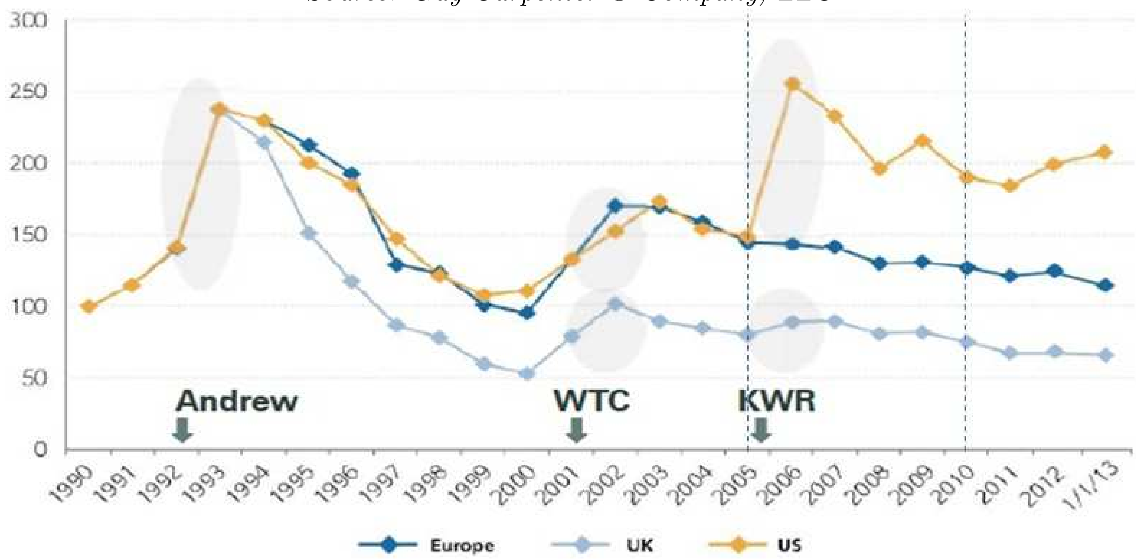

Figure 5.8: Regional property catastrophe RoL Index from 1990 to 2013
Source: Guy Carpenter & Company, LLC

Note: These figures display the average RoL of Catastrophe Excess of Loss reinsurance contracts over the years. Figure 5.7 displays the global RoL of the market since 1990, and Figure 5.8 displays the one per regions. Andrew refers to the 1992 hurricane, WTC to the 9/11 attacks, and KRW to the 2005 Atlantic hurricane season (Katrina, Wilma and Rita).

CHAPTER 6

Bidding behaviors on the Reinsurance Market

Work in cooperation with Martin M. Boyer, Professor of Finance, HEC Montréal

6.1 Introduction

The reinsurance market is the insurance market for insurance companies. The economic foundations of reinsurance include the transfer, the diversification and the pooling of risks. In this sense, reinsurance decisions can be seen as a combination of three decision making processes: risk sharing, risk management, and financial structure. The reinsurance market is even more important because it allows the economy to assume possible huge and highly correlated losses that, without this market, would have terrible consequences on other markets. Since insurers can reinsure other insurers and reinsurers need to be reinsured (via retrocession), the connected feature of this market ensures trustful and long term relationships between participants. However, these participants have heterogeneous profiles, expertise and information, which create different behaviors of premiums and coverage.

The goal of this paper is to explain what induces a reinsurer to bid for a given tranche of a particular reinsurance treaty on a specific risk. The study is based on a proprietary data-set that contains all reinsurers' quotations for different reinsurance tranches and contracts asked by primary insurers willing to buy reinsurance, all subsidiaries of one of the biggest global insurance company. There is no survivorship bias, either in the ceding insurers, or in the reinsurers, which highlights the importance of the data-set. As we do not have the information about the winning bid (i.e., the reinsurer that finally ended up leader on the contract), we will only concentrate on what we call the first round of the auction process: the bidding. The simple question we will attempt to answer in this paper is the following: What determines the bidding behavior of reinsurers? This question transcends the mere field of insurance economics and is also anchored in the economics of auctions. The primary step is to determine the explanatory factors of the bids, in order then to understand to what extent reinsurers are willing to accept a reinsurance premium, and the possible differences between the reinsurers' behaviors.

The global reinsurance market is one of the largest over-the-counter pure risk transfer market with 220 billion dollars reinsurance premium volume in 2011, and 230 in 2012. It has more than doubled since 1990 and shows a steady increase throughout the period, even with the financial crisis. In comparison, the premium volume of the insurance industry is about 4,613 billion dollars in 2012.[1] In contrast to the primary insurance market, contractual arrangements in the reinsurance market (called treaties) are less standardized and more global, as they involve larger amounts since portfolios of exposures are often exchanged. The reinsurance market cannot be compared neither to the insurance market in which the clients' capacity is way lower than the insurers' one; nor to financial markets with the multiple actors and mass behaviors. Very concentrated, the reinsurance market has a hundred professional reinsurers worldwide on the supply side. A.M. Best ranking of the largest reinsurers reports a huge difference of gross premiums written between the number one and the number fifty (from to \$33,719 to \$453). With 60% market share, the European reinsurers dominate the sector since 1998. Indeed, Europe is exporting underwriting capacity as it provides 60% of capacity and yields only 38% of premiums. The market concentration is very high, the top 5 global reinsurers hold 44% of market shares, and the top 10 global reinsurers 58%.

The economic importance of the reinsurance market transcends the pure insurer-to-reinsurer transaction. Reinsurance protection allows an insurer to reduce its financial responsibility and its probability of bankruptcy, and to increase its underwriting capacity (see Zimmer et al., 2012). Reinsurance advantages go even beyond since reinsurers often have an expertise that insurers do not have, and their relation improve the risk management and assessment of the insurer (see Jean-Baptiste and Santomero, 2000). Furthermore, the health (or lack thereof) of the reinsurance market has non trivial repercussions on the primary market where individuals and firms seek to find a financial entity to which they would like to put the losses they are exposed to. Berger et al. (1992), Born and Viscusi (2006) and Meier and Outreville (2006) have argued that shocks to the reinsurance market have a direct impact on the availability and pricing of primary insurance contracts. Since the reinsurance market is a way for primary insurers to raise capital at a lower cost than having to access capital markets directly (see Powell and Sommer, 2007; Mayers and Smith, 1990), it offers a possibility to reduce premiums on the primary insurance market. Being global in design and economic contribution, and being populated by only financially

1. Figures from FFSA and Sigma Swiss Re.

sophisticated players, one could argue that the reinsurance market is one of the most competitive financial markets in the world.

And although the reinsurance market is so important for the provision of insurance services, very little empirical research has been done, with Froot (2002) being the most famous exception. The most likely reason being that reinsurance is essentially a private relationship between sophisticated participants so that transactions are rarely made public, if ever. This explains also why transactions are mostly governed by intangible features, such as the reputation of the players, their capital adequacy and credit quality. When primary insurers request for reinsurers' quotations, they do not evaluate the reinsurers' offers only from the given bids, but also from the suppliers' attributes, such as the quality of services offered by reinsurers. These non-monetary attributes are not easily assessable as they can result from trust and confidence between a primary insurer and a reinsurer (see Asker and Cantillon, 2008 regarding scoring auctions with non-monetary attributes). Similar to the case of a policyholder who will not necessarily purchase insurance from the lowest priced insurer, an insurer may not opt for the reinsurer that made the lowest bid. In other words, it is very possible that the counter-party risk in the insurance/reinsurance relationship is so large that participants want to know and make sure that the reinsurer will be there financially in case their capital is needed.

The goal of our paper is to ultimately shed some light on the behaviors of reinsurers when deciding what insurance line of business to support, at what price and under what conditions. We seek to explain the bids made by the reinsurers using the risk characteristics of the treaties, that include the line of insurance, the number of tranches, the width of the tranches, etc. This research will also allow us to study whether reinsurers use different bidding behaviors and if so, what are their bidding strategies. As we shall see, we can find a rough taxonomy of reinsurer types according to their bidding profile across layers and types of risks, and how much there are willing to bid. In particular, we will show that reinsurer size is related to the type of bidding. The relationship is non-monotone, however, as the decision to bid on different types of tranches becomes either a niche strategy for small reinsurers or a bid-all-take-all strategy for very large reinsurers. Furthermore, the analysis we provide is, to our knowledge, the first systematic test of the theory developed by Plantin (2003, 2005). Plantin asserts that it is the most sophisticated institutions (that is, the institutions being more capable of correctly assessing the risks) that will accept to reinsure the low seniority tranches (that is, the low layers that have a higher probability of loss). What we find is that bids on low seniority tranches are mostly made by very large reinsurers that have the underwriting team to assess the risk appropriately through sheer manpower, or by much smaller reinsurers that, presumably, target specific types of risks because it is these precise risks that they understand and assess best. Our study will therefore examine the effects of diversification, and in particular the effects of the mutualization of the bids through different tranches and lines of business. In addition, since the rich data-set that we have spans six years, we will be able to examine the dynamics of the reinsurers' bidding behaviors over the years. Finally, we intend to explain the refusals to bid on a particular treaty or treaty's tranche. One can wonder whether bidding is a signal of "good will to stay in the market" even with the effect of the Winner's curse.

The main results of the chapter can be divided into three sets. The first one is that the kind of risk is an essential feature of the bid determination, the different lines of business do not have the same characteristics and the decisions regarding these risks are different. The second set of results is relative to the reinsurers' individual behaviors that vary across tranches, treaties, lines-of business and time, depending on the size, the capital and the expertise of the reinsurers. The last result is that the reinsurance market has evolved over the years, in particular with a growing complexity of the treaties' composition and an increasing number of actors, which have modified the reinsurance profession.

This chapter does not recall the literature as it was done in the previous chapter (Chapter 5). The next section introduces the data-set. The third section presents three examples of reinsurance treaties in order to see how reinsurance contracts work and have leads for the following analyses. Sections 4 analyzes the determinants of the reinsurers' bids. Section 5 discusses these determinants and the strategies chosen by the reinsurers when bidding (or not) on different tranches for different treaties. Finally, we conclude in Section 6.

6.2 Data collection

The primary insurers willing to acquire reinsurance protection usually request quotes (the bids) from many different reinsurance companies for a given reinsurance treaty in order to have an idea of the market and to choose more efficiently who will be leader on the tranche or treaty. The goal of our paper is to examine how reinsurers are setting the bids for a given tranche of a given treaty of a given risk. Before developing our analyses, it seems appropriate to describe the proprietary data-set that we will use in this paper.

6.2.1 Data description

The anonymized and proprietary data-set we shall use includes all the quotations asked by primary insurers, that are all subsidiaries of one of the biggest global insurance company from 2005 to 2010. It contains the bids offered by a relatively large number of reinsurers for a large set of tranches of multiple reinsurance treaties. In this sense, there is no survivorship bias, either in the ceding insurers, or in the reinsurers.

The data-set contains 19,614 entries over six calendar years (2005-2010), for 969 different treaties that have on average three tranches. 83% of the observations are bids or requests for bids for treaties that have four layers or less, with 28% of the reinsurance treaties having a single layer (see Table 6.6 in the Appendix). Cedent contacted on average 9 reinsurers for a quote of a given tranche for a given treaty. They received an average of 6 positive responses. This large number of answers provides us with the bulk of the information that we will need to ascertain the bidding strategy of the different reinsurers. Although a reinsurance treaty has three layers on average, the number of bids or requests for bids is over 20 observations. These are the observations that we will analyze in the data.

There are 41 different ceding insurers that are all part of the same big European insurance company. The cedents are distributed all over the world. One third of the treaties correspond to risks in France, one third to risks in the rest of Europe, and the last third in other countries of the world. A total of 19 lines of insurance are identified. Six cedents account for 49% of all the observations in the data-set, and 41% of the treaties (see Table

6.7 in the Appendix). There are 169 different reinsurer entities that correspond to 69 reinsurance companies, 10 of them never offered a quote. We end up with 59 global reinsurers, and their order in our data-set roughly corresponds to the A.M. Best ranking of the biggest reinsurers.

[INSERT Table 6.6 and Table 6.7 ABOUT HERE]

We observe in Table 6.7 an increase in the number of reinsurance treaties and layers in 2007, and then a drastic reduction in 2008 when the number of treaties and layers per treaty decreased. Treaty composition has changed over time so that reinsurance treaties have become more complex in 2010 than they were in 2005 and 2006. Reinsurance treaty length is also provided. And although the treaty length goes from a month to three years, over 95% of the treaties have a duration of exactly one year. Finally, the data provides crude information about some clauses and riders that are attached to the different layers such as the reinstatement premiums and the number of possible recoveries (i.e. the number of time the cedent can purchase reinsurance at the agreed upon price in the event of a loss) after the layer's coverage has been exhausted.

The quote can be a flat price (16% of the observations), or a rate of the gross net premium income (GNPI), i.e. the total premiums for the classes of business covered (84% of the observations [2]. For each bid on each tranche for each treaty, we can calculate the implied rate-on-line of the bid, no matter whether the quote is a flat price or a rate. This allows us to have a uniform measure of price per unit of coverage across the different layers. As we said earlier, we do not know what the winning bid for a given layer is; and we cannot even presume that the lowest bid is the reinsurer that ended with the contract anyway. The reason is that the cedent may be concerned with considerations other than price when accepting to reinsure with an entity. The cedent may care about the reinsurer's creditworthiness, claims expertise and the concentration of its business with one particular reinsurer [3].

Reinsurance treaties also vary in their structure as a function of the type of business for which reinsurance is sought (see Table 6.8). 80% of the treaties and 87% of the observations

2. The rate multiplied by the GNPI gives the flat price.

3. If a cedent chooses to buy reinsurance only to one reinsurer, she will be more exposed to the credit risk of this reinsurer. Getting reinsured by a set of reinsurers is a way of risk mutualization.

are associated with only seven lines of business. Ceding insurers are more likely to reinsure risks associated with natural hazards, property damage, general liability, accidents, motor, transports, and maritime exposures. The most numerous treaties in the data-set at those structured around either the natural catastrophe and property damage lines. They are also the ones that report the largest number of layers.

[INSERT Table 6.8 ABOUT HERE]

6.2.2 Data construction

The set of variables that will be used in the paper are the following and are related to the characteristics of the tranches, the treaties and the reinsurers (see Table 6.5 for a summary). The data-set comprises program and section names that have been coded in order to identify the 969 treaties (Treaty Id). It also includes the names of the 41 primary insurers[4] (Cedent), the year (Year, from 2005 to 2010), as well as the start and end dates allowing us to determine the length of the treaty (Duration, 97% of the treaties last for one year). One major aspect of the treaties is the lines of business (LoB). The data-set comprises 19 different types of insurance policies, as follows, sorted by number of treaties: Natural catastrophe, Property damage, General liability, Accident, Motor liability, Transportation, Maritime, Professional liability, All liabilities, Construction, Credit, Exhibition, Aviation, Assistance, Legal, Illness, Individual and collective life, and two miscellaneous LoB (Other 1 and 2) covering very small risks or set of risks. The first 7 LoB represent 87% of the observations while the last 7 LoB only represent 1% (see Table 6.8). We expect the LoB to have significant effects on the bid variability as a windstorm is not managed in the same way than a burglary or an accident.

The identification of the tranches within the treaties was possible from the limit (Limit), the priority (Priority) and other clauses[5]; we deducted the tranche position (Tranche)

4. Entries in the data-set were anonymized in order to remove all possibilities of identifying the information source. As a consequence, the names of the primary insurers have been removed and replaced by codes P101 through P141.

5. The data-set includes information about some special clauses and riders that are attached to the

and the possible parallel layers in case of more complex treaties (Overlap). We had to check and recode manually some layers due to the existence of these possible parallel layers. The layers can follow each other, for example from 1 to 5. There can also exist parallel layers in case of different option menu or subareas of the risk region. For example, in case of three parallel first layers, we will name the layers 1.1, 1.2, and 1.3. There can also exist several groups of parallel layers. For example, in case of a treaty with two parallel section on two tranches from the third layer, we will note the third layers $3a$ and $3b$, and the fourth layers $4a$ and $4b$, with $4a$ going above $3a$ and $4b$ above $3b$. Although the parallel layers have similar limit and priority level, they usually take into account different risks or have different exclusions (for example, earthquakes can be divided into ground-shaking and fire-following), or they include different geographic regions (for example, a high risk sub-region versus a low-risk sub-region), or provide different reinsurance clauses (such as different priorities, limits or recovery clauses).

From the information on the tranches' position, we could deduct the total number of tranches in the treaties (Total Tranche), which can be different from the highest tranche due to parallel layers. In the data-set, the highest possible tranche is 11; whereas the maximum total number of tranches in a treaty is 16 (for a treaty on Natural catastrophe with the highest layer being the 10th.). In addition, we have constructed a categorical variable according to the tranche level in the treaty (Tranche Scale) and separating the tranches into four different categories: the one-tranche treaties, the low layers, the medium layers and the top layers for multiple-tranche treaties [6]. The low layers correspond to low-end tranches, i.e. the working tranches and therefore the more risky; while the top layers correspond to catastrophe tranches for less likely events.

different layers, such as the annual aggregate deductible (AAD), which is the minimum annual loss before the reinsurer's liability kicks in; and the annual aggregate limit (AAL), which is the cap on the overall annual liability that a reinsurer may be responsible for. These two variables were also used in order to identify the tranches' numbers and position.

6. For instance a treaty with 6 layers has two layers in each category and a treaty with 7 layers has three low layers, one medium layer and three high layers. This choice of categories are consistent we believe with the way the cedents partition the treaties.

The data-set comprises the possible recoveries with the number of reinstatements and the reinstatement premiums (in percentage of the bid) that will allow to reconstruct the reinsurer's liability limit after the layer's coverage has been exhausted. This variable have been coded through dummy variables that give the nature of the recoveries (None, or Unlimited and free); or characteristic variables that give the number of recoveries according to their reinstatement premiums (Free, or Recoveries at *200%*, *150%*, *125%*, *100%*, *80%*, *66%*, *50%*, and *25%* of the quotation). This notation allows us to understand the effects of the recoveries on the bids as a layer usually have a mix of possible reinstatements and that we expect the quote to be influenced by the recoveries. The more frequent recovery clauses are "1 at 100%" (37% of the observations), "2 at 100%" (17%), "None" (12%), and "Unlimited and free" (8%).

The quotation, called Bid, is the main variable that we want to explain, it could be expressed as a flat or as a percentage of the GNPI (Gross Net Premium Income). They have all been transformed into flat prices and converted into Euros using the exchange rate at year end (the data-set comprises 15 different currencies). In the paper, all monetary variables have been converted into million in order to ease the reading. We also have computed the rate-on-lines (RoL), and we will be using the logarithm of the RoL (Ln RoL) in order to smooth the results. In addition, dummy variables on the fact to bid or not to bid have been created in order to understand the possible reasons why reinsurers offer a quote or refuse to underwrite reinsurance.

Speaking about reinsurers, the data-set comprises 169 reinsurers' entities that corresponds to 69 reinsurers [7] (Reinsurer); as well as the possible brokers (26 different brokers, plus no broker at all). As 83% of the tranches were proposed directly to the reinsurers, we created a dummy variable regarding the use or not of brokers (Home), but we do not expect that variable to have a significant effect. In addition, we have constructed a categorical variable according to the reinsurers' weights in the data-set (Reinsurer Size Group).

7. The data-set reports the name of the reinsurer' entity that gives the quotation, because some entities are responsible for specific cedents; however, the final liability comes back to the reinsurer group.

As the reinsurers' distribution is coherent with the A.M. Best 2011 fifty biggest reinsurers of the world, we expect that the reinsurance supplier will have significant effects on the bid (see Figure 6.2). We separated the reinsurers into three groups from jumps in the graphical distribution of the reinsurers (see Figure 6.1): the big reinsurers which correspond to the four biggest reinsurers (42% of the observations); the medium reinsurers, which correspond to 13 reinsurers (44% of the observations); and the small reinsurers, corresponding to 42 reinsurers (14% of the observations). In addition, 10 reinsurers did not bid at all (0,5%) and are naturally excluded of the analysis per reinsurers size group.

The data-set makes possible the determination of the number of reinsurers per tranche (Nb Reinsurer/Tranche), as well as who bids the lowest on each tranche and its amount.(Minimum Bid). Furthermore, we have the number of quoted bids per treaty and reinsurer (Nb Bid/Treaty X Reinsurer) and therefore the bidding rate across treaty for each reinsurer (Bidding Rate, i.e. the number of bid per treaty and reinsurer divided by the total number of tranches), and the probability to bid on the whole treaty. From the bidding rate, we could deduct a categorical variable depending on if the reinsurers bid on the whole treaty (bidding rate equal to one), on more than half of the treaty (bidding rate greater than 0.5) or on less than half of the treaty (bidding rate lower or equal to 0.5). Finally, in order to analyze the possible determinants of the decision to quote or not to quote a tranche, the dummy variable Bidder has been used as the dependent variable (equal to one if there is a positive bid, zero otherwise).

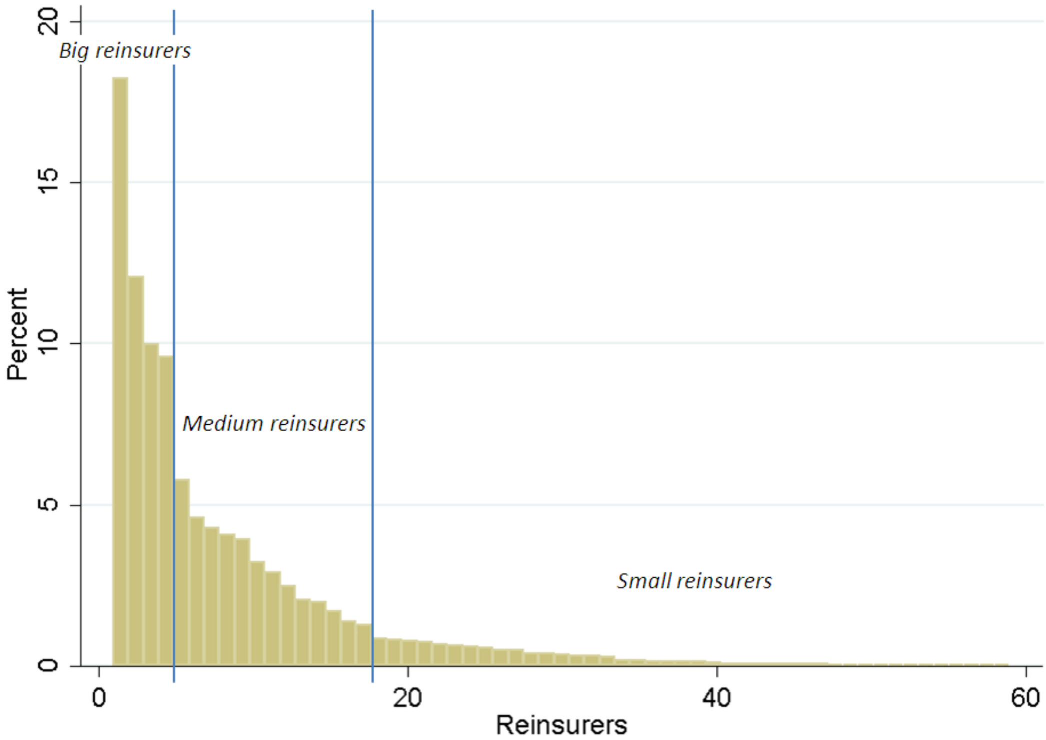

Figure 6.1: Distribution of the reinsurers' bids in the data-set

Note: This figure displays the histogram of the reinsurers according to their number of bids in the data-set.

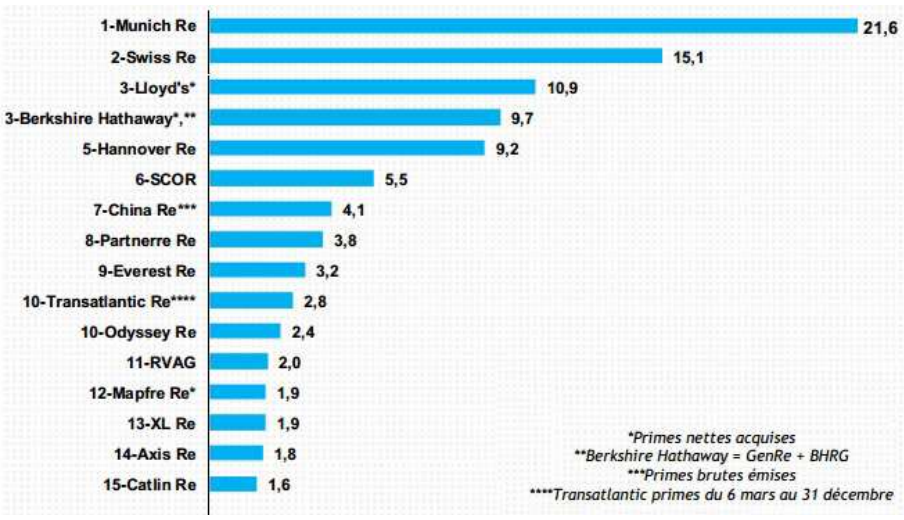

Figure 6.2: Ranking of the worldwide reinsurers
Source: SCOR, based on annual reports

Note: This figure display the 2012 global ranking of reinsurers based on the gross net written premium (in USD billion). It does not mean that this ranking is exactly the same than the one in our data-set.

6.3 Three examples of reinsurance treaties

This section displays examples of reinsurance treaties in order to have some insights on the structure and evolution of the reinsurance across lines-of-business, year, and layer, that will lead to a deeper discussion of the specific features of the reinsurance market.

Reinsurance contracts are very client specific so that different clients (i.e. primary insurers) are looking for different types of reinsurance structure depending on the line of business they are seeking to reinsure [8] In the following three tables, we provide examples of reinsurance treaties for a given primary insurer with, for each reinsurance layer and year, the limit in excess of the priority, the recovery clause (if any), the number of bids sought as observations, the number of reinsurers involved and the number of positive quoted bids. Furthermore, for the subset of reinsurers that offered positive quotations, the tables also report the average log of the rate-on-line, the average bid and the reinsurance dispersion. These reinsurance treaties are a property damage treaty (Table 6.9), a motor liability treaty (Table 6.10) and a catastrophe treaty (Table 6.11). The first two correspond to treaties per risk, and the XL Cat treaty is per event.

[INSERT Table 6.9 ABOUT HERE (Property damage risk)]
[INSERT Table 6.10 ABOUT HERE (Motor liability risk)]
[INSERT Table 6.11 ABOUT HERE (Catastrophe risk)]

We introduce and compare these three different treaties from different primary insurers with different lines of business to highlight the structural differences that can emerge in different reinsurance treaties, as well as the differences in time for the same type of risk reinsured by the same primary insurer. It also gives us an idea of the richness of the data that we were fortunate enough to obtain.

Evolution of contract structures We see in the three reinsurance treaty tables (i.e. Tables 6.9, 6.10 and 6.11) a clear evolution of reinsurance contract structure in time. For instance, the structure of the property damage reinsurance treaty (Table 6.9) did not

8. We need to make sure to compare what is comparable over the years. It is not exactly panel data due to the treaties' structure changes.

change for the first 5 years in the data-set, keeping five layers that have the same priority and limit year after year. Even the recovery conditions remained the same for those five years. However, the size of the reinsurance contract changed, as can be seen from the increase in the GNPI. This can be due to the number of individual contracts that are included in the primary insurer's book of business or merely due to changes in the market value of the insured portfolio. The number of reinsurers that were asked to offer a quote varied by close to 50% over the first five years, although the number of insurers that actually offered a strictly positive bid for a given tranche remained relatively steady over the years. We observe in 2010, however, that the same reinsurance treaty (i.e. the same primary insurer for the same line of business and sub-line of business) becomes a bit more flexible. Although the reinsurance treaty keeps the five layer structure that was present in the years 2005-2009, we see that layers 1, 3 and 4 are split into two or three different parallel layers. Although the parallel layers look similar, they usually take into account different risks or have different exclusions (for example, earthquakes can be divided into ground-shaking and fire-following), or they include different geographic regions (for example, a high risk sub-region versus a low-risk sub-region), or provide different reinsurance clauses (such as different priorities, limits or recovery clauses). In the case of the property damage contract, the parallel layers differ with respect to the clauses (in particular the recovery clauses).

In a similar manner, we observe that only minor changes affected the first layer of the automobile reinsurance treaty (Table 6.10) over the first 5 years. In the last year, the first layer split into two parallel layers with different priority levels and limits, at the same time as layers 2 and 3 merged into one large single layer. We notice that the global ceiling of the treaty did not change and remains 60 million over the years (only the insurer's retention moved from 1 to 2 million).

It is the natural event catastrophe reinsurance treaty (Table 6.11) that changed its structure the most over the year, and the most often. Figure 6.3 provides a more visual description of how dynamic the catastrophe reinsurance treaty changed over the years for the same primary insurer. In particular, we see changes in the number of layers, in the total amount of risk being reinsured, and in the size of the tranches. We also see in the later years changes in the structure of the parallel tranches.

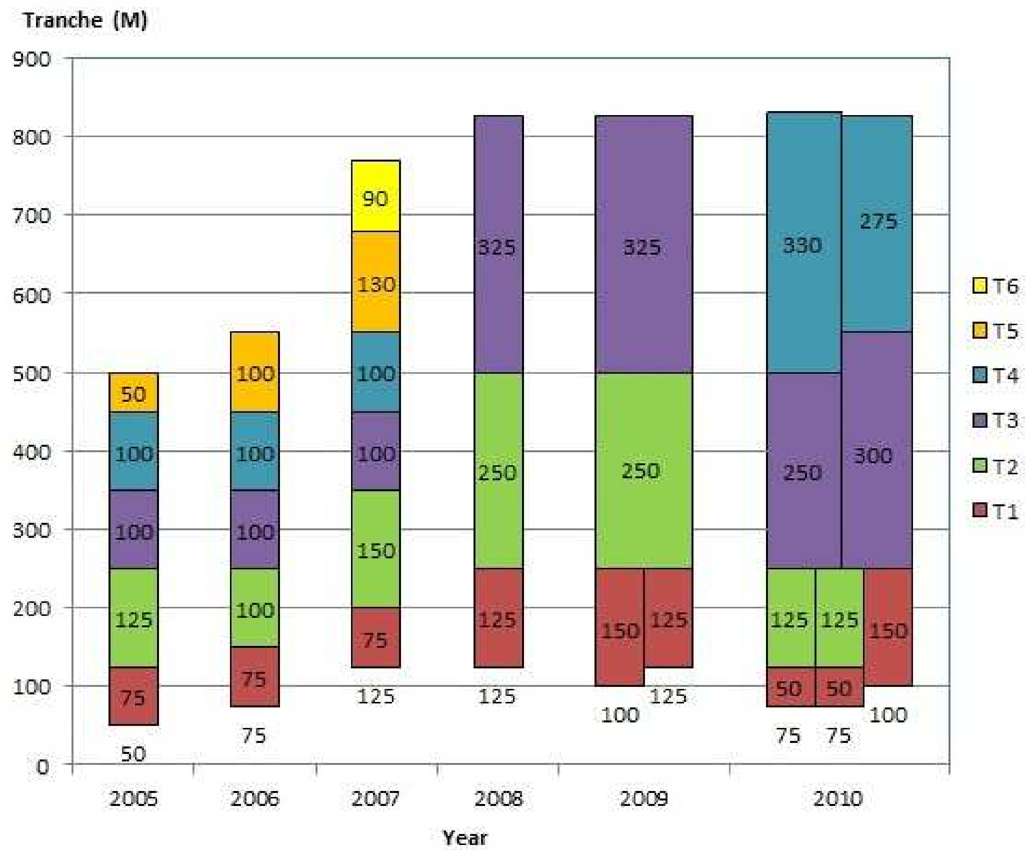

Figure 6.3: Evolution of the Cat treaty over the years

Note: This figure displays the evolution of the Excess of Loss Catastrophe treaty across the years, as described in Table 6.11.

This means that for the data which spans six years, the total capacity sought from the reinsurance industry in excess of the initial priority increased. It was 450 XS 50 million in 2005 versus 755 XS 75 million in 2010. The priority increased and the limit became wider. In 2008, the number of layers in the treaty fell from 6 to 3 layers; at the same time, the number of positive quotes offered by reinsurers was very low even though the number of reinsurers that were contacted was approximately the same as in the previous years. In 2009, the first layer was split into two parallel layers. In 2010, the treaty changed radically and became even more complex, with three working layers ending at the same 250 million total priority/limit mark, and then having two senior parallel tranches that did not have the same total capacity in the end.

In these examples, we can see a growing complexity of the reinsurance treaties between 2005 and 2010. It is interesting to see that the financial crisis of 2008 does not seem to have had much impact on the structure of their reinsurance market, except perhaps for the case of the natural event catastrophe reinsurance treaty where the contract structure in 2008 (and the number of bidding reinsurers) is radically different than in the surrounding years. But even in this case, it is not obvious that the cause of the change in the number of bids is due to the crisis rather than the change in the number of tranches. Perhaps the reduction in the number of tranches is due to the financial crisis, but the cause is not obvious, or even why that would only occur in the case of the catastrophe reinsurance treaty.

Bidders and bids for the three treaties We can observe in the three previous tables that each primary insurer seeking to reinsure the risk he is exposed to contacted several reinsurers for of the proposed reinsurance treaty. This is not always the case, as some reinsurers are specialized in one type of layer (working, mezzanine or senior). On average, 86% of the contacted reinsurers has responded by saying they were interested in having more information about the layer that the primary insurer is willing to cede. Of these interested reinsurers, 70% was willing to reinsure the layer at some price. In the first two years, more than 85% of the responses was positive. In the last four years, this rate fell to 60%. The fact that a reinsurer does not respond at all means either that he did not see the request, or that he wants to wait and see who will be leader and at what price in order to decide later if he will follow, or that is not interested to do business with the primary insurer in that year for that line of business.

Over the six years, approximately 60% of the contracted reinsurers was willing to reinsure a given tranche for a given price for these three specific reinsurance treaties. A reinsurer can refuse to bid for a risk because, for instance, he may have already used up all his risk-capital or capacity for this type of risk. This is different from a bid of zero that is essentially the result of studying the portfolio of risks that the primary insurer is trying to reinsure and then deciding that the portfolio does not provide the reinsurer enough information for him to bid on the tranche. This means that refusing to bid (after receiving the information of the primary insurer) can be interpreted regarding the risk portfolio's riskiness, while the mere fact that the reinsurer was contacted but did not care to even study the cedent insurer's proposal is difficult to interpret. Refusing to bid after obtaining the information means that the reinsurer either thinks that the primary insurer's portfolio of risks is too risky for him, or that the risk does not match his diversification policy.

Looking at the reinsurance premiums, we can analyze the distribution of the bids in each layer, and how they evolve over the years.[9] Firstly, we observe that the average rate-on-line decreases at the seniority of the layer increases. Interestingly, the fact that the average bid also seems to decrease as a function of the seniority of the layer even though the layers are generally larger as they become more senior. We see that the average bids (and a fortiori the average rate-on-line) reach their lowest level for a given treaty for a given year in most senior layers, thus suggesting that the risks that these senior tranches will ever be used are very low. For instance, in the 2005 property damage reinsurance treaty of Table 6.9, layer 5 has an average log of the rate-on-line of 3.48, which translates into an average $PayBack$ of approximately 29 (meaning that the average reinsurer believes that losses in excess of 75 million dollars are likely to happen once every 29 years). In contrast, layer 3 has an average log of the rate-on-line of 4.96, which translates into an average $PayBack$ of approximately 6 years (meaning that the average reinsurer believes that losses in excess of 30 million dollars are likely to happen once every 6 years). In 2009, the same two layers have lower rate-on-lines and higher payback. This either means that the market's competitiveness has increased with the years or that, for some reason, it is now believed that the risk of an important loss falling on the primary insurer has decreased. It is interesting to see that it is in 2008, the year of the financial crisis, that for all the non-working tranches (i.e. for the tranches 3-5), the average bid was the lowest.

The second interesting bid feature that can be seen in Table 6.9 is that the dispersion of the bid, as measured by the standard deviation of the bids, seems to generally decrease with the seniority of the tranche. But this reduction in dispersion may be only due to the fact that, on average, bids decrease in tranche seniority. When we normalize the standard deviation of the bids by the average bid (column labeled $SD(Bid)/Bid$), we see that the normalized dispersion of bids is distributed more or less homogeneously across the tranches with no discernible pattern within a given line of business.

9. Add a discussion on the type of reinsurer (major local, major world, specialized, new).

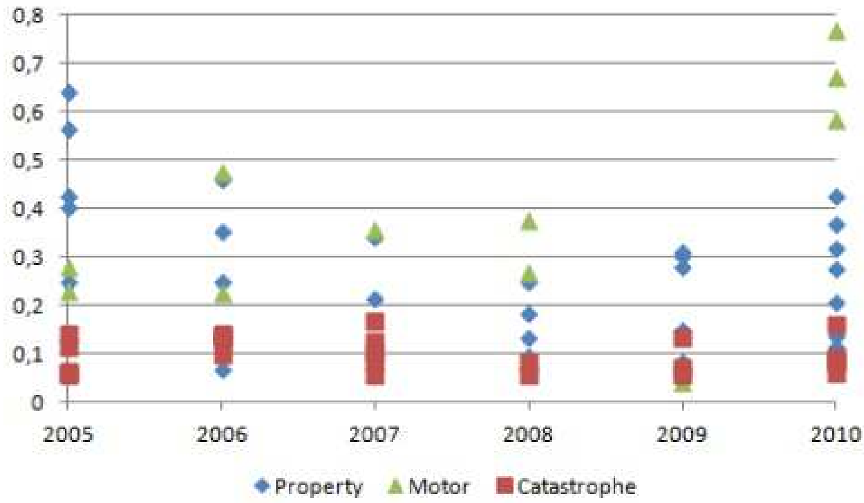

Figure 6.4: Evolution of the standard deviation normalized by the bid of each reinsurance treaty

Note: This figure displays the distribution by year of the standard deviation of each reinsurance treaty layers normalized by the average bid for the tranche; the graph excludes standard deviation values of zero and normalized standard deviations greater than 1.

Different LoB behaviours What is most interesting when looking across lines of business is that the normalized standard deviation of the bids seems to be the lowest for the most important natural event catastrophic reinsurance treaty. This result seems to say that there either is a higher level of coordination among reinsurance for high end losses (suggesting that the conclusion of Doherty and Smith, 1993, and Froot, 2001, about the lack of competition at the high end is problematic) or that these events are better understood by market players since the amount of moral hazard and adverse selection in the natural event catastrophic reinsurance market may be low. The lack of competition does not seem to hold following further scrutiny since there do not seem to be less reinsurers bidding for catastrophic tranches than for the other types of reinsurance treaties. Figure 6.4 provides a more visual depiction of how the normalized standard deviation of bids is distributed for the three reinsurance treaties that we examined more closely across years. We clearly see that the natural hazard catastrophe reinsurance treaty is the one that has, across the years, the lowest standard deviation normalized by the average bid of the three contracts.

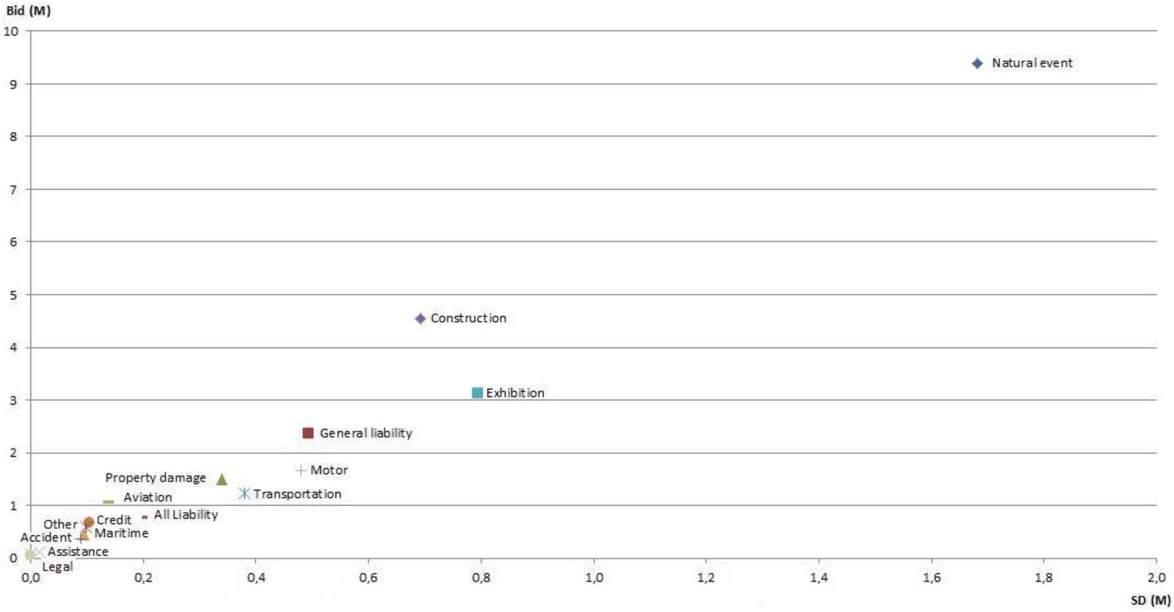

Figure 6.5: Line-of-Business according to their bid and dispersion

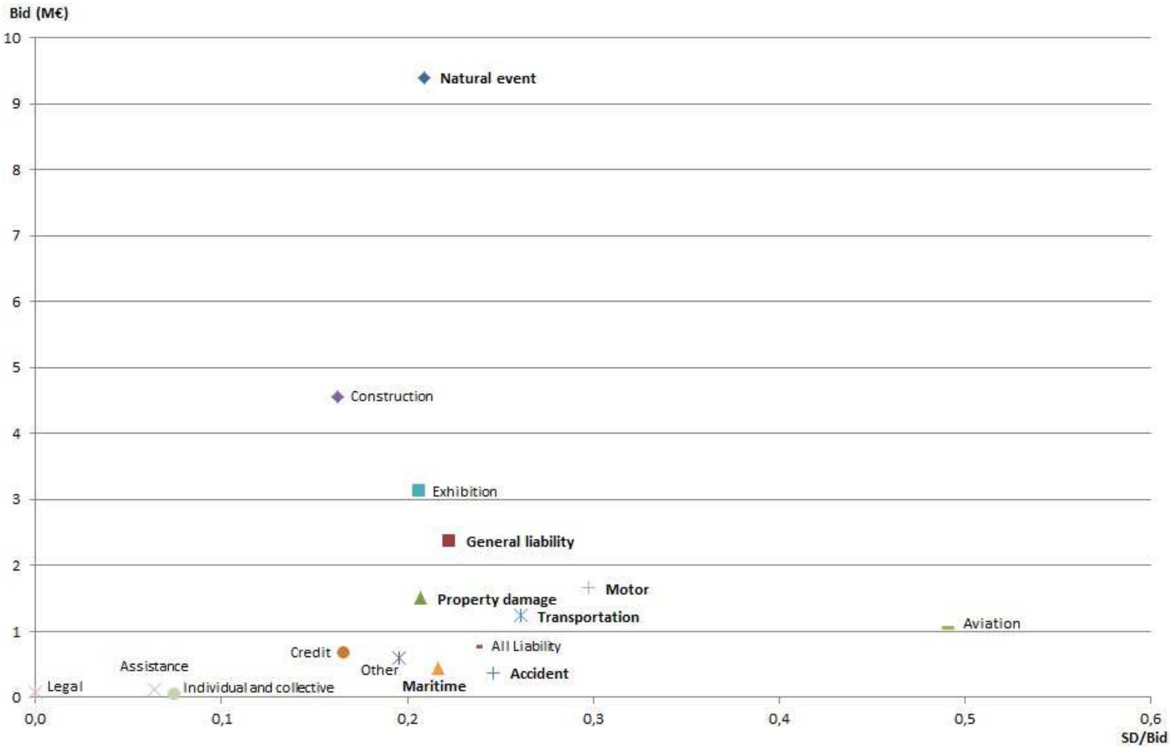

Figure 6.6: Line-of-Business according to their bid and normalized dispersion

Note: For each line of business, these figures respectively present the standard deviation and the normalized standard deviation by the bid as a function of the average bid, all years and all layers included. The seven biggest LoB are in bold.

When we look at the entire data-set, by line of business, Figure 6.5 shows the dispersion of the LoB according to the average premium and its dispersion. When looking at Figure 6.6 of the normalized dispersion as a function of the bid, we find an interesting pattern. As expected, we notice that the different LoB do not behave in the same way. Looking at the 7 biggest LoB (which embrace 87% of the observation, in bold in the second graph), we see that they have similar normalized standard deviation, but that the average bid in much higher for natural event, following by the general liability line and the other properties lines.

6.4 Explanatory factors of the reinsurers' bids

As the goal of the paper is to assess the structure of reinsurers' quotes, a primary step consists in examining model regressions that can assess the determinants of the reinsurance prices (or quotes) that are proposed by reinsurers in the data-set. The model regressions of Table 6.1 present "kitchen sink" regressions where the dependent variable is the reinsurer quote (in millions of Euros) for a given tranche for a given treaty, conditional on the bid being positive, and where the explanatory factors are relative to the tranche, the treaty and/or the reinsurer.

The first regression model (Model 1) of Table 6.1 focuses on a simple model where only the bid characteristics are presented. We observe that the quote is positively linked to the width of the tranche (i.e., the aforementioned *Limit* in millions of Euros) since the more a reinsurer is liable for, the more she should receive in compensation. A reinsurer who accepts to reinsure a larger tranche is exposed to a larger potential risk. The bid is also negatively linked to the *Priority* of the tranche, that is the amount of loss that an event can cause before a given tranche become in play. In other words, we expect the implicit deductible of a given tranche to be negatively linked to the bid as the frequency of larger losses should be smaller than the frequency of smaller losses, thus inducing a lower quote for tranches that have a higher *Priority*. A reinsurer who has a lower level of loss before his capital becomes "fair game" is more likely to have to pay, and therefore the premium should increase.

Table 6.1: Explanatory factors of the reinsurance bids

	Model 1		**Model 2**		**Model 3**	
	Coef.	*SD*	*Coef.*	*SD*	*Coef.*	*SD*
Explanatory variables:						
Limit	0.098 ***	0.003	0.096 ***	0.003	0.094 ***	0.003
Priority	-0.006 ***	0.001	-0.006 ***	0.001	-0.006 ***	0.001
Tranche	-1.248 ***	0.042	-1.241 ***	0.042	-1.257 ***	0.043
Total number of tranches	0.574 ***	0.031	0.589 ***	0.032	0.562 ***	0.033
Duration	-0.001 ***	0.000	-0.001 ***	0.000	-0.001 ***	0.000
constant	0.422 ***	0.117	2.257 ***	0.554	1.753 ***	0.189
Fixed effects:						
Recoveries	yes ***		yes ***		yes ***	
Years			yes ***		yes ***	
Reinsurers			yes ***		yes ***	
Lines of Business					yes ***	
R-squared	0.739		0.748		0.753	

Note: This table displays the results of several robust OLS regressions in order to explain the bids offered by reinsurers from a set of explanatory variables and controlling for fixed effects on the recoveries, the years, the reinsurers and the LoB.

The first regression also includes the total number of tranches ($TotalTranches$) in the treaty, and the number of the tranches equal or below the current one. We see that the total number of tranches is positively correlated to the bid, meaning that treaties with more layers are more expensive. It runs counter to Plantin (2003) that tranching makes CDO contracts more attractive to investors, then tranching in reinsurance should be more attractive to reinsurers so that cedents should have to pay less to acquire reinsurance. We analyze more precisely this effect later in the paper. However, the number of the tranche ($Tranche$), i.e. its seniority within the treaty, is negatively linked to the bid as the presence of more reinsurers in the working layers reduce the stress for services and assessment on reinsurers in the upper layers. It is interesting to see that the higher the layer (meaning that there are many reinsurers between the primary insurer and the layer), then the lower the premium. This suggests that subdividing into many layers may actually decrease the reinsurance cost to the primary insurer, as in Plantin (2003). The surprising effect is that there is a significant effect of the treaty composition on the bidding premiums, while reinsurers bid on layers. The regressions show that there is some information revealed to reinsurers with the shape of the treaty. For instance, ceteris paribus, the price decreases when we add an under-layer to the treaty, meaning that the reinsurers think the risk of the treaty has been reduced. Finally, we control for the duration of the contract. Reinsurance treaties of greater length are less expensive. Furthermore, the first model of Table 6.1 takes into account the possible recoveries that have a significant effect on the bids. All things equal, the bids are higher when there are no recoveries, or when the recoveries are free or unlimited; and lower when the recoveries are costly, which is to be expected. The first model does not include year or reinsurer indicator variables.

In the second model (Model 2) of Table 6.1, we include year and reinsurer indicator variables to control for aspects of the market that are unobservable. For the year dummy, we are thinking about the state of the economy, the term structure of interest rates, and the total capacity of the reinsurance industry. With respect to the reinsurer indicator variable, we are thinking of their particular underwriting expertise, their financial health and their overall reputation. The fixed effect regression reports that near one third (32%) of the bid variability if explained by the reinsurer differences. The R-squared reaches 0.92 in the between-reinsurer analysis and 0.71 in the within-reinsurer analysis. These results suggest that there exist several bidding behaviors that depend on the reinsurer. These strategies are what we want to define in this paper.

The line of business is included in the third model (Model 3) of Table 6.1. We can highlight the impacts of 7 biggest LoB, representing over 87% of the tranches. These lines of business are Natural Catastrophe, Property, General and motor liabilities, Transport, Accident, and Maritime. The regressions show that the bids are higher for the natural catastrophe and the general liability lines; and lower for the other lines of business. This result means that the LoB do not behave in the same way and that it will be interesting to differentiate them in our analyses in order to catch the possible bidding behaviors surrounding them. This "kitchen sink" OLS regression has interesting features that we exploit more in the coming sections.

Given these model results, it makes possible more in depth analyses of the bids in taking into account the effects of the tranches, of the treaties, of the reinsurer profiles, and of the market for reinsurance. The next section of the paper will examine further aspects of the market for reinsurance in relation with the tranche, the treaty, the reinsurer and the market.

6.5 Discussions and analyses of bidding behaviors

6.5.1 Tranches

We analyze here the reinsurer's decision to bid on a given tranche. Our hypothesis is that the decision to offer a quote on a given tranche depends on two things from the reinsurer's point of view. First, the reinsurer's underwriting expertise will tell her what is the possible distribution of losses and the appropriate price for each tranche given the information that was gathered through the underwriting process. This process should give the reinsurer a global idea of the inherent risk of the entire treaty. Consequently, a reinsurer should be willing to offer a quote for all the layers and tranches since the underwriting process gave her the proper measure of the possible loss distribution. The second aspect that should have an impact on the reinsurer's decision to offer a quote on a given tranche is the reinsurer's risk appetite for that tranche for that type of exposure. This means that even if a reinsurer has done the proper underwriting exercise and assessed the risk of the entire treaty properly, this reinsurer may be interested in only one particular tranche or subset of tranches because it fits better (in a portfolio sense) with its current book of business. Another possibility is for a reinsurer to be a specialist in a given layer (say the most catastrophic) so that it is interested in assessing properly only one part of the loss distribution of the cedent's portfolio of exposures.

Table 6.12 presents the average bidding rates over the treaties with specific number of tranches, i.e. the proportion of positive quotes from a given reinsurer on the layers' treaty. On average, the reinsurers have offer a positive bid on 56% of the treaty' tranches, or 2.44 bids per treaty and reinsurers. The bidding rate is decreasing as the total tranches of the treaty increase. The table also gives the probability that a given reinsurer will bid on all the layers of a treaty at the same time. As expected, the likelihood of bidding on all the layers is a generally decreasing function of the number of layers. It is clearly not automatic for a reinsurer to offer a quote on all the tranches at the same time. In approximately 55% of the cases the reinsurer does not offer a quote on all the layers of the reinsurance treaty. Taking into account only the reinsurers who bid at least on one layer of the treaty, 27% of the bidding reinsurers do not propose a quote on all the treaty' tranches.

[INSERT Table 6.12 ABOUT HERE]

Looking more closely at the data in the following table, we observe a clear difference in the reinsurers' strategy as 73% of the reinsurers who bid at least on a part of the treaty always bid on all the tranches of the treaty. Table 6.13 reports the average bid and RoL and their standard deviations depending on if the reinsurers bid on all the treaty's layers, on more than half of the treaty, or less. What is interesting is that bids are much higher when the reinsurer offers a quote on only one subset of the treaties. Reasoning in RoL, the reinsurance premiums are much lower when the reinsurers bid on all the treaty for treaties with less than 6 layers, and higher for larger treaty. This is expected as most reinsurers do not bid on all the treaty for large total tranche treaties.

[INSERT Table 6.13 ABOUT HERE]

There are two explanations for the negative link between the quote and the number of tranches on which the reinsurer offers such a quote for a given reinsurance treaty. The first is that the more specialized reinsurers are those that offer a better service to the cedent so that the risk assessment is more accurate and can help the cedent to invest in processes that reduce the overall exposure of its entire portfolio of risks (and especially the part of the portfolio that the cedent retains). The second explanation is that the underwriting process is expensive to the reinsurer. If one believes that this underwriting process is a fixed cost, then the fact that a specialized reinsurer has to recoup all the fixed cost on a subset of layers instead of the entire treaty will necessarily increases the quote. With respect to the higher standard deviation of the quotes when they are limited to a subset of the tranches, one is forced to imagine that this is due to a difficulty in assessing properly the statistical properties of a truncated distribution as opposed to the entire distribution of losses for the entire portfolio of exposures. Furthermore, the average bid and RoL in log of the treaty increase with the number of tranches as large treaties include all distribution of losses and risk assessment is then more delicate.

The decision to bid on all the tranches rather than on a subset of tranches depends also on the type of exposure that the cedent is trying to reinsure. For instance, if the risk is more complicated or requires more capital to cover, a reinsurer may be willing to accept a smaller number of layers in its portfolio. Table 6.14 highlights the likelihood of bidding on all the tranches of a treaty for the top 7 lines in our data-set. As we see, the likelihood of bidding on all the tranches is the smallest for the natural catastrophe line with 29% of all reinsurers and 51% of the bidding ones bidding on the whole treaty. This makes sense regarding it is the largest treaty LoB with 3,31 layers per treaty on average (see Table 6.15 for the distribution of the number of tranches for each of the 7 major LoB). In relation with the average number of layers per LoB of Table 6.15, the other lines who have the lowest bidding rates are the liabilities lines. In line with common intuition, the natural catastrophe line is the one that requires the most capital whereas the liability line is the one that requires the most expertise.

[INSERT Table 6.14 and Table 6.15 ABOUT HERE]

As the number of tranches has an impact on the quote, it seems relevant to see what is the distribution of the quotes as a function of the number of tranches there are in a reinsurance treaty. Table 6.16 presents, by year of the reinsurance treaty, the average quote, RoL and the standard deviations as a function of the level of the tranche (the one-tranche treaty apart). Consistent with the regression, the price is much lower in the top layers than in the lower layers. This is to be expected since the higher the tranche, the lower is the probability that a loss will reach it. Reinsurers prefer the top layers to the lower ones not only because the higher layers are less likely to get hit; but also, and perhaps more importantly, they are presumably less correlated with capital market events. In other words, higher layers have a beta that is more likely closer to zero than lower layers. This means that a lower risk premium needs to be associated with these higher layers. We could say that low tranches are more risky than top tranches, but that top tranches are more ambiguous than low tranches. If reinsurers prefer high tranches, this means that they are more risk averse than ambiguity averse. In order to test this hypothesis, we can assume an actuarial "fair pricing", and therefore deduce the ratios of probability of occurrence. The RoL ratio of low tranches by high tranches is 1.65, meaning that the low tranches are 65% more risky than the high tranches. We also find that the medium tranches are 33% more risky than the high tranches. The single tranches are close to the medium ones as they seem 36% more risky than the high tranches. Furthermore, the high tranches have much more dispersed RoL (with a standard deviation of 1.24 in comparison of 1.07 for the other layers of the treaty). These tranches can be considered as more ambiguous because the occurrence probability of a loss seems low but difficult to assess precisely. The single layers are also very volatile.

[INSERT Table 6.16 ABOUT HERE]

We also note that the bids have evolved over the years, especially in the low tranches for which the variation across time is larger as well as the standard deviations. Low tranches are more risky than high tranches due to a higher beta, and there can be ambiguous depending on the risks, due to the difficult assessment of the hitting probability. The difficulty of assessing risks at the working layer level is because these are more likely correlated with market events. In comparison to low-end tranches, we observe a change in the average quote for high-end tranches that is less pronounced. More importantly, however, the change in the standard deviation of the quotes of high-end tranches is much smaller than for the low-end tranches. In terms of price level, we note a dramatic increase in prices in 2008 for low-end tranches, amidst the financial crisis. The RoL ratio of low tranches by high tranches falls from 1.67 in 2007 to 1.57 in 2008. For these low-end tranches, the average price almost doubled at the same time as the standard deviation of these prices went up almost three-fold. Furthermore, it is interesting to note that the price did not increase that much in 2008 for mid-level and high-end tranches and that the standard deviation actually went down. The table also presents the results using the average rate-on-lines in logarithm, that also increase dramatically at the low-end, as well as the standard deviations of the rate-on-lines.

6.5.2 Lines of business

The line of business has a non-trivial impact on the bid quoted by the reinsurers for the business of the ceding insurance company (see Table 6.1). We will focus our discussion on the three most important lines of business, that are General liability, Property damage and Natural catastrophe. We recall that reinsurance quotes to reinsure property risks were significantly lower than the reinsurance quotes for liability and natural catastrophes, everything else equal. An explanation is that the liability and natural catastrophe lines are much more volatile and have much thicker tails (or higher second and fourth moments) than the property damage line. The property damage line is the "normal" short tail insurance line of business as it is about repetitive, numerous, small risks. Insurance jargon talk about *attritional risks* as they are opposed to extreme risks. Another explanation is that property risks are less ambiguous than the other two lines. Indeed, information is more precise and available, small and repetitive risks having large historical data that allows to assess more precisely the risks. The extreme risks' assessment, such as natural catastrophes, on the other hand, cannot be based on historical data, it needs stochastic modeling, and is subject to lots of ambiguity linked to imprecise hypotheses and models. As for liability risks, they can be of various amounts and difficult to assess as they are really dependent of justice decisions. The ambiguity surrounding that kind of risks is really high.

In the case of the general liability line, we talk about long-tail line of business, since the loss exposures take potentially a long time to settle. Product liability and medical malpractice losses can be claimed and paid many years after the actual occurrence since it often takes a long time to realize that an unfortunate event occurred and caused damage and to go on trial. In the insurance risk management, insurers use different methods and time lag to calculate the required reserves to held in order to be able to meet all future claims according to the duration of forecasting losses of insurance contracts. Liability contracts can take up to 30 years to occur, while property contracts only takes one year, except in case of dispute. In the reinsurance treaties for liability risk, a stability clause is automatically included in order to share the future inflation between the cedent and the reinsurer, which modifies the priority in function of the inflation rate. Furthermore, the information asymmetry between the different actors in the insurance and reinsurance market for liability risk is much larger than in many other lines of business; while the need for a long-run relationship between the two parts is high. As the aggregate distribution of these risks is very difficult to assess, it becomes essential that the reinsurer's expertise is up to the best standards of the industry. All reinsurers do not have that expertise, less than 40% of all reinsurers offers a bid for a liability risk in our data-set. The expertise allows the reinsurer to offer a more precise bid, closer to the real risk; but, more importantly, it allows to advise the insurer. That monitoring role is far more important in this kind of risk than in property lines. As a result of the importance of the underwriting process, the consulting role, and the need for well-capitalized actors, only few number of players in the industry has such an expertise, and reinsurance costs increase. Such difficulty in assessing the risk properly also leads to quotes that should be much more volatile.

In the case of natural catastrophe, the loss exposures tend to be more in the short-tail line category (it is hard for an important windstorm to go unnoticed when it hits a region) but their specificity is such, in the sense that losses can be very important and their frequency very low, that a lot of capital is needed to cover these rare events. On the reinsurance market, the bidders are much more willing to reinsure these risks. The supply is very important, the catastrophe risks representing 32% of the observations in our data-set, and more than 80% of reinsurers bid. Indeed, the appearance on the reinsurance market in the 90's of Bermudian actors, due to regulatory and fiscal reasons, have enhanced the market for catastrophe risks. They were initially monoline, specialized in catastrophe risks, but have sometimes grew to become more generalist reinsurer with an important activity. Reinsurance market participants consider these catastrophe reinsurance treaties as "commodities" as the number of transaction far exceeds the number of exposures. The winning reinsurance quote is more likely to be one that is the least costly to the cedent since the reinsurer's expertise is less likely to matter for the cedent. And as a large pool of capital is needed to offer the proper protection to the cedent, participants in the natural catastrophe reinsurance market are more likely to be well-capitalized reinsurers, but the relationship between the cedent and the reinsurer does not have to be on the long run, and the expertise is less needed.

As shown in Table 6.17, the average bid is much higher in the natural catastrophe line of business than in the two other lines. When we control for the size of the tranches (that is, we use the rate-on-line instead of the bid itself), the average rate-on-line for the natural catastrophe line of business behaves closer to the property damage line in terms of the average by tranche level, but the standard deviation is much different (lower for low tranches and higher for high tranches). The catastrophe line is cheaper than the property damage line, with lower standard deviations, which is coherent with the fact that the supply is very large for these risks. The RoL is very high for the liability line, especially in one-tranche treaties and low tranches. These findings also hold if we reason in terms of RoL ratios in order to find the scales of the occurrence probabilities (assuming an actuarial fair pricing of the tranches). The property damage line is more risky than the catastrophe line, while the risks of catastrophe and liability lines are close. Furthermore, the liability line displays the highest standard deviations, revealing that the assessment is the most difficult and ambiguous, while the number of observations is smaller and only 39% of the reinsurers bid at least once on this line (81% of all reinsurers bid on the catastrophe line, and 51% on the property line).

[INSERT Table 6.17 ABOUT HERE]

6.5.3 Reinsurer characteristics

We examine here whether there are reinsurer specific characteristics that influence the decision to bid on a tranche of a specific treaty, and/or the decision to offer such or such quote. We divided the reinsurers in our data-set into three groups according to the total number of bids they have made in the six years under study (see Figure 6.1). The distribution of the reinsurer in our data-set according to their number of bids is relatively coherent with the A.M. Best ranking of the fifty biggest reinsurers on the planet, which tells us that our sample is significantly representative of the reinsurance market. We have the top 4 reinsurers that represent over 50% of the bids, i.e. the well-known global reinsurers. The next 13 reinsurers account for 40% of the total number of bids. There are also 42 smaller reinsurers that account for 10% of the total number of bids. Finally, 10 reinsurers over the 69 did not offer any bid in the six years under study.

The following table (Table 6.18) highlights the average quoted reinsurance premium by year for the three categories of reinsurers, and then the implied rate on line according to the same cross tabulation. Note that the more often a reinsurer bids on tranches, the lower are the quotes on average. A possible explanation is that reinsurers who bid very often are spreading the cost of the underwriting assessment over a very large number of bids. These large reinsurers are also perhaps more diversified and overall experts in the global insurance and reinsurance market so that they have less need for capital buffer when offering quotes. The counter point is then of course that reinsurers that offer bids less frequently should perhaps be thought of as specialist reinsurers.

[INSERT Table 6.18 ABOUT HERE]

It is interesting to note that the quotes of the large reinsurers are on average lower and less dispersed than the quotes for the small reinsurers. Large reinsurer quotes are on average approximately half of that of the smaller reinsurer quotes. Regarding the bids across reinsurer size and the treaty year, we can see a higher variation in the average bid of small reinsurers, suggesting that they are more prone to fluctuations in supply and demand side shocks. This then begs the question of the possibility that small, specialized reinsurers should be more likely to be present in lines of business that require more expertise. Using the same three lines of business that we used previously (property, liability, and natural catastrophe), we see in Table 6.19 below that the small reinsurers are aggressively bidding for tranches that are associated with the line of insurance that requires less expertise and has the shortest tail: the property line. For the other insurance lines (that is, the insurance lines that require a bit more expertise or capital), small insurers offer quotes that are on average larger than for the medium and large reinsurers in terms of bids. In terms of RoL, small reinsurers bid aggressively low on the catastrophe line. They mostly bid on catastrophe risks as 74% of the small reinsurers bid on catastrophe line, 33% on property line and 19% only on liability line. Regarding liability risks, small insurers do not have the necessary expertise and capital to be able to face losses that have a long tail. As a result, even if they participate in the market by assessing the distribution of losses, they may not want the business in reality. For losses that are catastrophic in nature, the reinsurers see an opportunity as the catastrophe line seem to be the less "risky" in the sense that if no event occurs, it is a good investment for short term. Another interesting feature of the above table is that, except for the property damage line of business, the quote made by small reinsurers is much more dispersed than for the four largest reinsurers. This suggests again that small reinsurers have more heterogeneous underwriting practices, in line with common practice intuition. Furthermore, they are quite specialized. Over the 42 small reinsurers, 19 only bid on one LoB, including 13 bidding only on the catastrophe line.

[INSERT Table 6.19 ABOUT HERE]

The 42 small reinsurers, that account for less than 10% of the bids, not only choose which treaty to offer a quote on, they are also less likely to bid on all the tranches of a treaty as shown in Table 6.20. As we see, the 42 small reinsurers bid on all the tranches of a treaty only 26% of the time, and 52% when counting only the bidding reinsurers (the reinsurers bidding on at least one tranche of the treaty).

[INSERT Table 6.20 ABOUT HERE]

Given that small reinsurers are more likely to offer a quote on only one subset of the tranches, it seems appropriate to examine what are the tranches that reinsurers bid upon. Table 6.2 suggests that small reinsurers are relatively more likely to bid on the working tranches. Another interesting feature of this table is the fact that larger reinsurers offer quotes that are, tranche by tranche, lower on average and less volatile than the medium-size reinsurers' quotes. In turn, the quotes of the medium-size reinsurers are on average lower and less volatile than the small reinsurers' quotes. The larger the reinsurer, the lower the bids. Looking closely to the tranche scale categories, it seems that it is the medium-size reinsurers that propose the smallest quotes for single-layer reinsurance treaties and for the top tranches of multiple-layer treaties, and for which those quotes are the less dispersed. Furthermore, the rate-on-line gives similar results with small differences in the sense that low and middle layers seem to be quoted the lowest per small reinsurers, meaning that these reinsurers could be specialized on some layers over others. Indeed, 45% of small reinsurers only quote small reinsurance treaties (with less or equal to 4 layers), 40% only quote large

Table 6.2: Bid and RoL per reinsurer size group and tranche scale

Reinsurer size group		**Bid** One tranche	**Bid** Low layers	**Bid** Middle layers	**Bid** Top layers	**Bid** Total	**RoL (in log)** One tranche	**RoL (in log)** Low layers	**RoL (in log)** Middle layers	**RoL (in log)** Top layers	**RoL (in log)** Total
Big reinsurers	*mean*	2,49	4,11	2,99	1,63	2,90	4,33	5,28	4,23	3,13	4,24
	sd	3,80	9,71	6,17	2,94	6,75	1,48	1,09	1,15	1,36	1,48
	freq	443	1 643	1 810	1 569	5 465					
Medium reinsurers	*mean*	2,01	5,66	4,27	1,71	3,84	4,20	5,25	4,28	3,23	4,30
	sd	3,13	11,38	8,24	3,30	8,36	1,54	1,07	0,99	1,07	1,33
	freq	363	1 367	1 451	1 158	4 339					
Small reinsurers	*mean*	2,32	7,44	6,60	3,06	5,63	4,89	5,21	4,19	3,24	4,33
	sd	4,44	15,80	12,01	4,75	11,91	1,37	0,97	0,97	1,22	1,33
	freq	80	387	372	312	1 151					
Total	*mean*	2,28	5,12	3,87	1,81	3,56	4,33	5,26	4,25	3,18	4,27
	sd	3,61	11,28	7,87	3,33	8,12	1,50	1,07	1,07	1,24	1,41
	freq	886	3 397	3 633	3 039	10 955					

Note: The table displays the average bid, logarithm of the rate-on-line and the associated standard deviations, as well as the frequencies, according to the reinsurer's size and the level of the tranche within the treaty.

reinsurance treaties (more than 4 layers), 5% only quote one-layer treaties. The 10% left quote a mix of large and small treaties.

Looking at the connections between primary insurers and reinsurers, Figure 6.8 displays the paired insurers and reinsurers according to the number of bids the reinsurer offers to the insurer. This network graph clearly shows that natural catastrophe risks are "commodities", business as usual, which explains the very large supply; while general liability risks are less successful with a low supply. The market for property damage risks is more balanced.

[INSERT Figure 6.8 ABOUT HERE]

Another characteristic of small reinsurers is that they are unlikely to remain market participants for a very long time. Indeed, when we look at these 42 smaller reinsurers, only 8 provided at least one positive quote for each of the 6 years. Limiting our analysis to the last five years of the data (there are only 11 small reinsurers that offered 46 quotes in that first year, 20 reinsurers for 103 quotes in 2006, 25 reinsurers for 255 quotes in 2007, 20 reinsurers for 176 quotes in 2008, 24 reinsurers for 240 quotes in 2009 and 32 reinsurers for 331 quotes in 2010), only 10 small reinsurers offered at least one positive quote in each of the last 5 years. These 10 small reinsurers account for 535 of the 1105 quotes that were made by small reinsurers in the years 2006-2010 (and 575 of the 1151 quotes over the six years). As small reinsurers account for only 10% of the total number of quotes in the data-set, we can see that 5% of the total quotes come from small reinsurers that have not had a full experience of the market dynamics for more than 5 or 6 years.

6.5.4 The lowest bids on the reinsurance market

As much as we would like to know what reinsurer ended up winning the contract for each tranche of each reinsurance treaty and under what condition, the data-set does not give us that information. What we can examine instead is what reinsurer made the lowest bid. If this was common value auction and all reinsurers were the same, we know that it is the reinsurer that quoted the lowest price that would have ended up with the contract. There is therefore a certain logic to studying what are the characteristic of the lowest quote per tranche for each reinsurance treaty in the data-set.

We must remain aware, however, that in reinsurance markets it is up to the ceding insurer to choose the reinsurer that will become the tranche or treaty leader. The cedent chooses the leader after receiving all the different reinsurer quotes. She can decide to have the same leader for all treaty or different leaders for each tranche. And whatever reinsurer is chosen, it will be its quoted price (after some further negotiations between the cedent and the lead reinsurer) that will have to be accepted by all chosen reinsurers that are willing to have part of the action. The reputation of the leading reinsurance is important because it guarantees the seriousness of the transaction. This means that the name of leading reinsurer has to be made public in order for other reinsurers to follow its lead. In the end, several reinsurers, generally a sub-sample of those who bid in the first place, will be responsible for losses in a given tranche of a reinsurance treaty, but not necessarily each in the same proportion. The leader will be responsible for the largest proportion.

The reinsurance market use complex auction mechanisms. This market is a sealed-bid auction as each bidder independently gives a bid without seeing others' bids. The reinsurance market has features from the private-value model in the sense that the bidders are heterogeneous and the individual bids depend on the level of capital, the reinsurance capacity, the diversification of their risks, their quotas of coverage, etc. The reinsurance market also has features from the common-value model as the risk of the treaty might be uncertain and the bidders might not have the same information (signal) from the cedent. This signal can be different according to the relationship history between the cedent and the reinsurer and the degree of trust between the two. Furthermore, the private bids of the reinsurers are impacted, in their risk assessment processes, by their beliefs on the risk characteristics, and by their ambiguity aversion around the knowledge of these characteristics.

The reinsurance market is not a first-price auction as the lowest bid is not necessarily the winning bid. The leader is not necessarily the reinsurer that proposed the lowest quote. The cedent does not only care about the price as her reinsurance decision will impact her financial stability in case of default of the reinsurer. The cedent will take into account the bid, but also the relationship with the reinsurers, their solvency strength, their expertise (in function of their need for monitoring), etc. The cedent company must therefore make an arbitrage between the quote that is the most attractive (i.e. the lowest), and quotes that are possibly higher but that originate from more "serious" reinsurers. Asker and Cantillon (2008) develop a scoring auction model in which the buyer care about other attributes than the price. The hypothesis is that the suppliers do not have the same private information and that their fixed and variable costs may be different. They define "pseudo-types" of suppliers and a set of scoring rules in order to rank the bids. On the reinsurance market, the reinsurers may not have the same production costs as well. In the risk assessment, the fixed costs can be the purchase of modeling tool, and the formation of the teams; the variable costs are the available workforce, the understanding of specific risks and the own information. This defines the expertise of the reinsurer, and the possible monitoring role. In addition, the capitalization degree is also an important attribute. Primary insurers based their decisions on the "seriousness" of the reinsurer that is linked to its expertise and its level of capital.

We can expect that, in long tail lines and in capital extensive lines, the size of the quote will be relatively less important than the potential services offered by the reinsurer and its credit quality, provided that the cedent values those two things. A longer relationship will be needed for long-tail lines; while a solid capital, even on the short run, will be needed to cover catastrophe lines. Both conditions are not necessarily filled by the same reinsurers. All else equal, cedent will weigh more the quality and the seriousness of the reinsurer in the case of liability (for its expertise) and of natural catastrophe lines (for the capital), while in short tail lines, such as in the property and in the accident lines, the lowest quote will be more likely to be the winning quote. Put differently, when risk assessment becomes essential such as in long tail lines, then a long-term relationship between the leader and the ceding insurer become more important since the leader needs to be reliable and trustworthy. In shorter tail lines, reinsurer quality is less important so that the leader is more likely to be one of the reinsurers that provided the lowest quotes. Regarding catastrophe lines, the supply being very large, cedents usually have the choice between several possible reinsurers.

In parallel to Figure 6.8, Figure 6.9 displays the paired insurers and reinsurers according to the number of lowest bids the reinsurer offers. The network graph lightens up compared to the first one and shows that the bidding reinsurers mainly also offer a lowest bid. On average, 27% of the offered bids is the lowest of the tranche. However, 90% of reinsurers that bid on property and liability lines also offers at least once a lowest bid; while it is only 83% for catastrophe line. The catastrophe line is a convenient line in which refusing to reinsure could be a bad signal of leaving the market.

[INSERT Figure 6.9 ABOUT HERE]

However, it is not sure than the lowest bid will be the final price as non-monetary attributes have to be taken into account. Asker and Cantillon (2008) develop a scoring auction model in which the buyer cares about other attributes than the price. They link the consumer's taste for quality and the supplier's social surplus that he can generate, i.e. his "pseudo-type". We can assume here that the reinsurers' "pseudo-types" are linked to their size and position on the market, and that they will generate different qualities and prices according to the market share and to the risks.

Table 6.3 presents the distribution of what type of reinsurer (big, medium and small) has the lowest quote as a function of the tranche scale. For multiple-layer treaties, the lowest reinsurance price seems to be shared between big and medium size reinsurers, depending if we take into account the bid or the rate-on-line. However, the market is still mainly held by the biggest reinsurers as they always bid lower than the median bid for multiple-layer treaties. Meanwhile, the medium size reinsurers have strengthened their position on the market by proposing interesting prices and developing new expertise. For one-layer treaties, medium size reinsurers are the ones quoting the lowest both in terms of RoL and bids. Looking at the evolution across time, the 2007 year seems to have been the last year of the "supremacy" of big reinsurers on the market.

The small reinsurers do not necessarily compete with the other reinsurers as they have much higher minimum reinsurance premiums. We could have expected small reinsurers to take risks and bid frenetically low in order to run through the market and appeal primary insurers. However, they do not necessarily have the means to assess properly the risks and such behaviors could be dangerous, they cannot set very low premiums without expertise and sufficient capital. Nevertheless, they are generally specialized in a specific kind of layers or risks, and they can be useful to primary insurers for short term relationships in order to seal "holes" in their reinsurance programs. Indeed, we do not expect the small reinsurers to be leaders but more probably followers as they do not necessarily have the recognition by their pears. This strategy of "niche" expertise seems to have paid off as we can observe an increase number of lowest bids within small reinsurers from 2008, in particular in small and medium tranches.

For Table 6.22, we link the type of insurer (big, medium and small) with the type of exposure (property, liability and natural catastrophe) to see if indeed there is a relationship between the type of reinsurer and the probability of having the lowest quote. As we predicted, small and more specialized reinsurers are more likely to have the lowest bid for the line of insurance that is less unknown, which is the property damage line [10]. In terms of RoL, it is the largest quotes, due to the fact that they mostly bid on top layers. Medium

10. They also gives the lowest bid for general liability but the sample is too small to be significant.

Table 6.3: Lowest bid and RoL per reinsurer size group and tranche scale

Reinsurer size group		Bid					RoL (in log)				
		One tranche	Low layers	Middle layers	Top layers	Total	One tranche	Low layers	Middle layers	Top layers	Total
Big reinsurers	*mean*	2,41	2,61	2,10	1,32	2,05	3,93	4,99	3,88	2,64	3,85
	sd	3,87	5,75	4,28	2,71	4,41	1,36	1,13	1,19	1,68	1,63
	freq	153	455	448	448	1 504					
Medium reinsurers	*mean*	1,62	3,64	2,08	1,09	2,26	3,77	4,95	3,98	2,88	3,97
	sd	2,70	8,23	4,22	2,47	5,50	1,70	1,16	1,06	1,30	1,46
	freq	125	400	412	338	1 275					
Small reinsurers	*mean*	1,89	5,45	6,01	3,02	4,67	4,83	5,07	4,02	3,04	4,16
	sd	3,56	13,62	13,75	4,80	11,37	1,68	0,92	1,09	1,38	1,43
	freq	32	134	127	113	406					
Total	*mean*	2,04	3,41	2,60	1,45	2,47	3,96	4,98	3,94	2,78	3,94
	sd	3,42	8,27	6,45	3,03	6,20	1,57	1,12	1,12	1,51	1,54
	freq	310	989	987	899	3 185					

Note: The table displays the average of the lowest bids, of the logarithm of the rate-on-lines and of the associated standard deviations, as well as the frequencies, according to the reinsurer's size and the level of the tranche within the treaty.

reinsurers quote the lowest in terms of RoL for the property risks. Meanwhile, the four biggest reinsurers are able to quote the lowest for the other two lines, capital or expertise focused. Medium size reinsurers are generally in the average.

[INSERT Table 6.22 ABOUT HERE]

Across time, we observe in Table 6.21 an increase in the average size of the minimum quote, and much more so when it is one of the smaller reinsurers that had the smallest quote. It is true that risks and risk assessment have evolved such that the number of tranches-treaties doubled from 2005 to 2010. Nevertheless, across all reinsurer types, the average minimum bid increased sizeably. Another interesting feature of the table is the rapid increase between 2008 and 2009 in the probability that the lowest quoting reinsurer was going to be a small reinsurer.

[INSERT Table 6.21 ABOUT HERE]

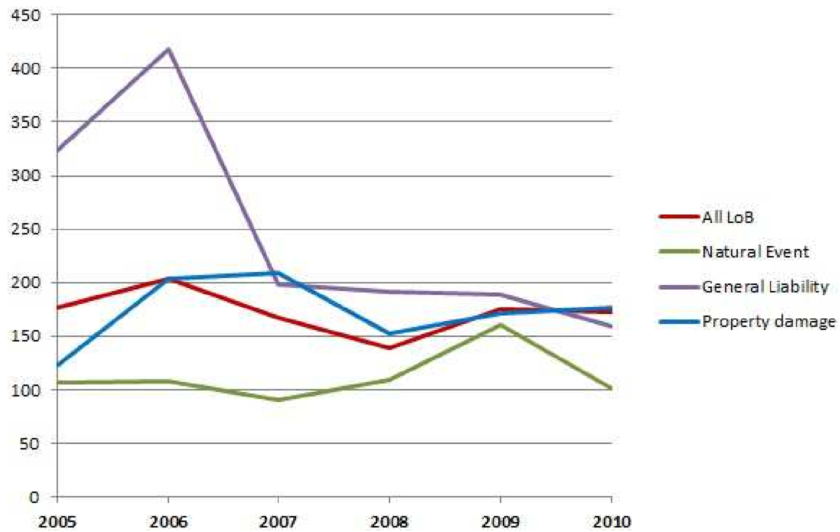

Figure 6.7: RoL by line-of-business over the years in our data-set

Note: This figure displays the average RoL of the three main LoB, as well of the global RoL of our data-set from 2005 to 2010.

6.5.5 Bidding and tranching effects over time

In the vein of the last table, it appears relevant to examine the inter-temporal dynamics of our data-set, and more specifically of the treaty construction. We know from the previous sections that there was a increase in the reinsurance premiums between 2005 and 2006, and between 2008 and 2009. These two periods correspond to two shocks in the reinsurance industry: the 2005 hurricanes and the Subprime crisis. 2005 was an unprecedent and most active Atlantic hurricane season in recorded history, with Katrina, Rita and Wilma hitting North America, which increased claims for reinsurers of about 50 billion dollars, compared to a yearly insurance premium of 180 billion dollars all risks put together.[11] Only one reinsurer went bankrupt, which records of the strength of the reinsurance market, of the fact that reinsurers assess relatively correctly the risks and know their core of business. This shock impacted more violently the United States than the rest of the world. As our data are mainly centered in Europe, the effects of Katrina are lower but the effect of the crisis is high. Figure 6.7 shows these effects, in comparison to Figures 5.7 and 5.8 of the previous chapter.

11. Figures from SCOR

However, the effects of the crisis are much higher. The subprime crisis cost 600 billion dollars to the reinsurance market, a relative small cost compared to the real estate market in the US (11,000 billion dollars).[12] In our data, the 2008 year has been marked by a significant increase in the number of cedents seeking reinsurance protection (see Table 6.7). Interestingly, Table 6.18 shows that the financial crisis is marked with an high raise in the bidding aggressiveness of small reinsurers. What is interesting in that table is that, despite the financial crisis, the average minimum quote did not increase between 2008 and 2009 (if anything it decreased across all types of reinsurers), although the dispersion of the minimum quote did increase sensibly for the subgroup of smaller reinsurers. The way reinsurers quote highly depends on the risks' occurrence in the previous years. If losses have been high and treaties "abnormally" hit, the reinsurers will increase their quote in the following year. Furthermore, if the risk seems to increase, the risk assessment will be modify. Another interesting findings, that we can see in Figure 6.23, is that, while small reinsurers had increased their bidding rate in 2007, this bidding rate has dropped violently between 2007 and 2008 (from 51% to 33%) in a much more important way than for the other two reinsurer size group.

Despite the shocks, the reinsurance market has evolved gradually. Furthermore, we examine here to what extent the operating of the reinsurance market and the structure of the reinsurance treaties have evolved. As previously seen, the structure of the reinsurance treaties seems to have become more complex over time, with more layers and more parallel composition of layers. The treaties' composition has changed and the actors do not behave in the same way as before. Figure 6.24 clearly shows that reinsurers are less likely to be on all the treaty's tranches in 2010 compared to 2005. Treaties seem to have become more complex, bigger and wider, making it difficult for reinsurers to bid on all the parts. The question here is whether there was an increase in the complexity of reinsurance treaties over the years, and what could explain the fact that pooling the contracts is more optimal than separating them. It should exist an economic interest for the insurer making it more rational to create one big reinsurance treaty than lots of small ones. Several reasons can be

12. Figures from SCOR

provided. A first one is that the risks have evolved and the treaties have adapted; or that new risks have appeared, in line with new regulations, new technologies or new liabilities. This is linked to the second explanation that is a change in the risk assessment processes on the reinsurance market. New risks could have appeared but the risks did not necessarily change in depth. Risk models have spread, taking into account more parameters, more risks (such as credit or default risks), and therefore reinsurance treaty optimization has been done with more factors and has allowed the creation of complex structures. For instance, the three commercial modeling tools to assess catastrophe risks (AIR Worldwide, EqeCAT, and RMS), which are extensively used by the reinsurance market, have been updated numerous times since 2005. In particular, after the Atlantic hurricane season of 2005 [13], the reinsurance industry have recorded major losses and actors have questioned the way to assess these risks. The catastrophe models have then incorporated changes in taking into account large effects of climate change, more risks and more correlations. These changes have appeared on the market 2 or 3 years later, time to develop and to include in the modeling tools, which is consistent with the data. Pooled contracts could be less expensive due to correlations between risks. The complexification comes from a better understanding and a better segmentation of the risks according to their region and characteristics.

Another explanation is that the reinsurance market has changed. On one hand, the change in regulation, with the on-going implementation process of the new Solvency II Directive, insurers had to adapt their reinsurance coverage in order to meet the capital requirements. On the other hand, the oligopolistic market that is reinsurance has expanded, new actors (that is, new reinsurers) and new products (such as Catastrophe bonds) have appeared, and have modified the competition on the reinsurance market. The primary insurers have adapted in order to match their needs with the new actors' ones. A final reason is relative to communication matters, and pooling treaties allows to better differentiate the risks and explain the behaviors of reinsurance demand.

13. In 2005, the Atlantic hurricane season was the most active in recorded history, with major hurricanes such as Katrina, Rita and Wilma. The 2004 season was also very important.

Furthermore, the fact that the low-end of the treaties is more tranched than the high-end, and that low tranches have generally smaller limits than the top ones, it is linked to the recovery clauses. Indeed, low-end is more likely to be exhausted and the cedent will have to pay the reinstatement premium whereas the probability that it will be exhausted a second time is quite low.

What is surprising is that the data-set is organized in terms of layers, the reinsurers bid on layers while there is a significant effect of the treaty composition on the bidding premiums. The regressions show that there is an information revealed to reinsurers with the shape of the treaty that makes the price go down if there is an under-layer. According to the big insurance company who gave us the data-set, there appears to be an important ratchet effect in the global reinsurance market in the sense that if a layer is added on top of the treaty, then the prices of all the layers underneath increase. In a sense, adding a tranche on top means that the cedent now anticipates that there was a shift in the aggregate distribution of losses such that more protection is needed. This means that the implied probability that lower tranches are going to get hit has increased. This ratchet effect is, however, one-sided since if a tranche is added at the bottom of the treaty then prices of the upper tranches are not affected. The prices are not linear link to this layer effect. The treaty composition is a signal for reinsurers, so reinsurers optimize their quote from the loss distribution revealed by the treaty. What is revealed to the reinsurers is linked to the shape of the market. On the demand side, primary insurers construct the treaties in order to match their needs with what they anticipate being what the different reinsurers want. The cedent does not want to exclude a part of the market that could be specialized on one of their risks. They are looking for different reinsurers that will accept different tranches in order to have the more interesting quote for each tranche depending on the reinsurer's abilities (from the arbitrage between the price and the seriousness of the bidder); and to diversify the credit risks of the reinsurers.

6.5.6 To bid or not to bid, that is the question

The last aspect of our analysis concerns the reinsurers' decision to offer a positive quote on a given tranche for a given treaty. To do so, we use a Probit analysis where we model the probability of having a positive bid for such a tranche. There are many reasons why a reinsurer would not want to offer a quote on a tranche or on a treaty. One reason may be that the reinsurer studied the risk, evaluated how it fit in its entire portfolio and decided that it was not appropriate for its book of business. In this case the reinsurer's quote is 0 in our database. Another possibility is that a reinsurer was invited to study the risk exposure and to offer a quote, but did not provide request information about the risk. In that case the data-set reports a "no quote" information. In other words, the reinsurer could have not responded to the invitation to offer a quote, or the reinsurer could have decided to "wait and see" who will be the leader and delay its decision to enter or not in the market. For the purpose of our study (i.e., what makes a reinsurer want to offer a positive quote on a given tranche for a given treaty), a quote of zero and a no quote are treated the same.

We would expect the probability of quoting to be positively linked to the tranche and the priority as the highest layers are the less risky ones and the less likely to be hit. We would also expect the probability of quoting the tranche to be negatively correlated with the limit as the reinsurer's liability is smaller. Nevertheless it could also be explained if the limit was positively linked to the probability of quoting because large tranche imply large reinstatement premiums which are generally paid if the layer is exhausted and for which the gains for the reinsurers are important. We should also have a positive linked between the probability of quoting and the total number of tranches as a large treaty gives information on the loss distribution of the primary insurers and is a signal that decreases asymmetric information.

Table 6.4 presents the Probit regression results. The main result we get from these regression analyses (see Model 1) is that the wider the tranche (high limit), the less likely a reinsurer will quote on it, but the more catastrophic (high priority) it is, the more likely it will receive a bid. This means that reinsurers care about the amount of capital they have to put aside to cover a loss in a given tranche such that more capital intensive tranches are less attractive, and at the same time reinsurers value low frequency tranches more. What

Table 6.4: Probit regressions on the probability of quoting a tranche

	Model 1		Model 2		Model 3	
	Coef.	*SD*	*Coef.*	*SD*	*Coef.*	*SD*
Explanatory variables:						
Limit	-0.001 ***	0.000	-0.001 ***	0.000	0.002 ***	0.000
Priority	0.001 ***	0.000	0.001 ***	0.000	0.001 ***	0.000
Tranche	-0.020 ***	0.007	-0.020 ***	0.007	-0.020 ***	0.008
Total number of tranches	-0.012 ***	0.005	-0.003	0.005	0.028 ***	0.005
Duration	-0.000	0.000	-0.000	0.000	-0.000	0.000
constant	0.239 ***	0.029	0.385 ***	0.041	0.918 ***	0.159
Fixed effects:						
Recoveries	yes ***		yes ***		yes ***	
Years			yes ***		yes ***	
Lines of Business					yes ***	
Reinsurers					yes ***	
R-squared	0.009		0.025		0.127	

Note: This table displays the results of Probit regressions for the binary response problem of quoting a positive bid or not, from a set of explanatory variables and controlling for fixed effects on the recoveries, the years, the reinsurers and the LoB.

is surprising in the first regression model (Model 1), however, is that the more tranches there are in a reinsurance treaty, the less likely those tranches will receive a bid. However this does not hold when we control for the years, the coefficient of the total number of tranche being non-significant. The other results hold even when we control for year effects (see Model 2). When we control for the line of business and the reinsurer fixed effects (see Model 3), as expected, the limit of a tranche as well as the total number of tranches become positively linked to the probability of quoting on it.

Model 3 of Table 6.4 displays different results than model 1. The decision to reinsure a layer is more likely to be positive when the limit is high, surprising but explainable because the reinsurer can expect to receive large reinstatement premiums in case of recoveries; when the priority is high, because the risks are less "risky" (but probably more ambiguous); and when the number total of tranches is high, because it is a greater signal on the primary insurer' risks. In addition, Model 3 shows that the tranche is negatively correlated with the probability of quoting. This is linked to the predominance of big and medium reinsurers that bid on the entire treaty (bidding rate close to one).

Another interesting feature is that the regression of Model 3, which reports an R^2 of 0.13, fits better the sub-population of the small reinsurers, with a R^2 of 0.24 and the same coefficients' signs. The decision of quoting is more easily explained for small reinsurers as their bidding rate across treaty is smaller, then their bidding way is more predictable. On the opposite, the four biggest reinsurers only have a R^2 of 0.08, but the effect of the explanatory variables are in line with the ones we expected: the probability of quoting is negatively correlated with the limit and positively correlated with the priority, the tranche, and the total number of tranches in the treaty.

6.6 Conclusion

The paper analyses the determinants of the quotes given by reinsurers from the characteristics of the tranche (the limit, the priority, the recovery clause), of the treaty (the treaty's composition, the line of business), and of the bidder (the reinsurer quoting or not). A first important finding is relative to the tranches and the lines of business. On one hand, while the reinsurers bid on layers, the treaty's composition is a signal of the loss distribution, decreasing information asymmetries. The lower tranches are the more risky, more likely to be hit and more correlated to financial markets; while the higher layers may be more ambiguous but more profitable for reinsurers, seen as good investments. Furthermore, a bidding reinsurer mostly bids on all the layers' treaty as the risk assessment process is a fixed cost that needs to be spread. On the other hand, the bids depend on the lines of business according to the needs in capital and expert advice. The cedent will not make the same arbitrage between the quote and the "seriousness" of the reinsurer in terms of capital and/or expertise according to the LoB she is trying to reinsure.

A second important finding is relative to the reinsurers' individual behaviors that vary across tranches, treaties, lines-of business and time, depending on the size, the capital and the expertise of the reinsurers. The idea was to define possible bidding behaviors of the reinsurers, and whether the bidding strategy follows a diversification approach (i.e., many different layers for many different risks) or a niche approach (specializing in specific tranches, or specific risks). The first result is that the more often reinsurers bid on a tranche, the lower are the quotes, revealing that the reinsurance market is a competitive market despite being oligopolistic and over-the-counter. The second result is that different strategies can be found according to the reinsurer's size. Globally, we can say that the larger the reinsurer, the lower the quote; however there are some specifics. Big reinsurers have a higher possibility of diversification, they usually bid on all the treaty's layers in order to optimize their assessment process. They prone a long-term relationship with the cedents, and bid low due to high skill expertise in order to keep their leader's position. However, their supremacy has evolved as new participants have appeared on the market, which are likely to become leader as well. Medium reinsurers are specialized in one-layer treaties, but have become important market actors from 2008 with increasing expertise skills and decreasing quotes. We believe that medium reinsurers have followed a Beauty context pricing process in order to sustain on the market. Finally, small reinsurers are a very heterogeneous population with no global expertise, or with a very specialized one. They follow a learning process and their quotes are very volatile. Despite a high default risk, they can be used to seal "holes" in the treaties, especially for short-term lines of business.

The last result, linked to the previous one, is that the reinsurance market has evolved over the years, in particular with the growing complexity of the treaties' composition, the larger number of actors on the market, and the modification of the risk assessment process. These factors have modified the reinsurance profession. Further research is needed in order to determine more precisely the evolution of the reinsurance market over time, and the extents to the changes in the treaties, the assessment and the participants.

Given these results, further research is needed for in-depth analyses about the reinsurance market. This very particular market should be modeled through auction model taking into account characteristics of the reinsurers, of the risk that is not necessarily well-known, as well as the solvency strength of the reinsurer, its expertise, and the relationship history with the client.

6.7 Appendix

Please find hereafter the tables and figures used in this paper.

Table 6.5: Summary of the main variables

Variables	*Number of different observations*	*Variables*	*Average*	*SD*	*25% perc.*	*Median*	*75% perc.*
Treaty	969	Limit (M)	38.82	67.06	4	13.42	42.5
Layer	2848	Priority(M)	88.73	246.64	2.5	10	50
Year	6	GNPI(M)	403.68	1104.09	12.06	87.07	374.52
Client	41	AAD(M)	18.8	40.7	2	5.92	15
Reinsurer	169	AAL(M)	49.53	48.13	7	30	100
Broker	27	Bid (M)	3.56	8.12	0.31	0.9	2.75
LoB	19	RoL	171.36	255.48	30.49	10.48	185.25
Sub-LoB	35	Ln (RoL)	4.27	1.41	3.42	4.26	5.22

Note: This table displays a description of the variables included in the data-set. The table shows the number of different observations for the qualitative variables, and the main descriptive statistics for the quantitative variables, in million of euros.

Table 6.6: Evolution of the treaties in terms of number of layers across time

Number of layers	2005	2006	2007	2008	2009	2010	Total
1	38	33	41	45	54	60	271
2	24	28	41	32	36	30	191
3	27	36	35	28	41	52	219
4	14	13	28	16	26	22	119
5	7	8	21	12	24	19	91
6	1	4	15	0	8	4	32
7	1	1	5	2	3	3	15
8	0	1	1	1	3	3	9
9	0	1	1	1	1	3	7
10	0	0	2	2	0	0	4
11	0	0	0	1	1	2	4
12	0	0	0	0	3	1	4
13	0	1	0	0	0	0	1
14	0	0	1	0	0	0	1
16	0	0	0	0	0	1	1
Total	112	126	191	140	200	200	969

Note: This table displays the number of treaties with a certain number of layers for each year. There are 277 treaties with only one layer, and 3 treaties with 11 layers. We notice the evolution of the number of layers within the treaties across the years.

Table 6.7: Observations and treaties per primary insurer (cedent) across time

Primary	**Nb of observations**							**Nb of treaties**						
insurer	2005	2006	2007	2008	2009	2010	Total	2005	2006	2007	2008	2009	2010	Total
P101	163	275	466	400	322	490	2,116	13	16	17	17	19	17	99
P102	220	136	555	270	285	416	1,882	14	10	25	10	13	17	89
P103		266	312	394	415	372	1,759		5	11	10	12	11	49
P104		106	113	384	508	382	1,493		5	6	11	11	11	44
P105	72	246	271	203	285	283	1,360	5	11	8	10	9	9	52
P106	81	67	181	142	161	395	1,027	10	11	14	10	10	12	67
P107	117	101	182	173	193	203	969	10	8	9	11	11	11	60
P108	142	36	224	28	137	275	842	8	6	10	4	10	13	51
P109	4	31	416		111	132	694	2	2	23		8	5	40
P110	95	113	105	78	118	101	610	7	6	5	5	5	5	33
P111	177	136	76	65	63	85	602	6	5	3	2	2	3	21
P112		24	177		153	229	583		2	6		5	5	18
P113		3	27	37	178	229	474		1	2	4	5	6	18
P114	83	56	148	35	47	92	461	5	3	6	2	2	4	22
P115	10	39	69	106	133	83	440	2	2	2	2	7	3	18
P116	22	40	82	75	94	108	421	2	3	4	3	3	3	18
P117	97	69	79	21	28	98	392	3	2	2	1	3	4	15
P118	65	78	61	30	48	80	362	5	5	4	3	3	4	24
P119	18	20	69	68	111	42	328	3	3	5	5	4	2	22
P120	42	60	59	43	48	53	305	3	4	3	5	5	5	25
P121		12	80	61	77	66	296		2	4	5	5	4	20
P122		0	106	38	53	67	264			4	2	2	3	11
P123					83	128	211					6	6	12
P124					65	143	208					4	5	9
P125	12	6	38	52	58	38	204	1	1	3	3	3	3	14
P126	54	63	71				188	5	6	6				17
P127	28	28	28	32	36	28	180	1	1	1	1	1	1	6
P128			84		20	72	176			4		1	2	7
P129	28	21	26	16	39	36	166	4	3	2	2	2	2	15
P130				54	41	26	121				3	3	3	9
P131				18	39	56	113				1	3	3	7
P132	9	11	13	17	24	28	102	1	2	2	2	2	2	11
P133				18	20	32	70				2	2	2	6
P134				36	8	24	68				4	3	3	10
P135					24	14	38					11	3	14
P136					16	16	32					1	1	2
P137					0	24	24						1	1
P138					4	13	17					4	5	9
P139	6						6	1						1
P140	4	2					6	1	1					2
P141						4	4						1	1
Total	1,549	2,045	4,118	2,894	4,045	4,963	19,614	112	126	191	140	200	200	969
Average	67.35	73.04	147.07	103.36	109.32	130.61	478.39	4.87	4.67	6.82	5.00	5.56	5.26	23.63

Note: This table displays the number of observations and the number of treaties which are contained in the data-set for each cedent and each year. Note that the primary insurers are numbered from P101 to P141 in order to keep the confidentiality, and that there is no survivor bias.

Table 6.8: Distribution of the data-set across Lines of Business (LoB)

LoB	**Observations**		**Treaties**		**Layers**
	Freq	Percent	Freq	Percent	per treaty
Natural event	6,180	31.51%	175	18.06%	4.10
Property damage	4,307	21.96%	174	17.96%	3.41
General liability	1,685	8.59%	117	12.07%	2.47
Accident	1,020	5.20%	92	9.49%	2.03
Motor liability	1,398	7.13%	79	8.15%	2.51
Transportation	1,194	6.09%	77	7.95%	3.01
Maritime	1,244	6.34%	65	6.71%	3.31
Professional liability	686	3.50%	55	5.68%	1.96
All Liabilities	674	3.44%	37	3.82%	2.95
Construction	294	1.50%	32	3.30%	1.69
Credit	297	1.51%	16	1.65%	2.75
Exhibition	419	2.14%	15	1.55%	2.20
Aviation	99	0.50%	14	1.44%	2.93
Assistance	16	0.08%	8	0.83%	1.25
Legal	1	0.01%	1	0.10%	1.00
Illness	10	0.05%	1	0.10%	1.00
Individual and collective	4	0.02%	1	0.10%	1.00
Other 1	50	0.25%	7	0.72%	1.00
Other 2	36	0.18%	3	0.31%	2.00
Total	19,614	100.00%	969	100.00%	2.94

Note: This table displays the number of observations and the number of treaties in frequency and in percent across the different lines of business, as well as the average number of layers per treaty. Other 1 and 2 are miscellaneous small risks.

Tables 6.9, 6.10, and 6.11: Three examples of reinsurance treaties

Note: The following three tables (Table 6.9, Table 6.10, and Table 6.11) display three different treaties, which are related to three different risks (property damage, motor, and natural catastrophe).

The tables first show the characteristics of the treaty with the structure of the different *layers*, the *limit* and the *priority*. The layers can follow each other, for example from 1 to 5. There can also exist parallel layers in case of different option menu or subareas of the risk region. For example, in case of three parallel first layers, we will name the layers 1.1, 1.2, and 1.3. In case of several groups of parallel layers, we will note the third layers $3a$ and $3b$, and the fourth layers $4a$ and $4b$, with $4a$ going above $3a$ and $4b$ above $3b$.

The tables also show, for each tranche, the possible deductible (*aad*) and *recovery* clauses and the gross net premium income (*GNPI*). The recovery clauses can be read as following: "4 free, 1 at 50%" means that the first four reconstructions of the layer are free, and the fifth one will be charged half the reinsurance premium.

Then, they display the number of observations (*Obs.*) which represents the number of lines in the data-set; the number of reinsurer's responses *(reinsurers*) which is the number of responses the layer had received, responses that can be positive (bid) or null (refusal to underwrite the layer); and the number of *bids*, i.e. the number of positive responses for the layer. Finally, the tables report information on the quotations: the average logarithm of the Rate-on-Line (*ln(RoL)*), i.e. the bid divided by the limit for a thousand euros ; the average *bid*, its standard deviation (*SD(Bid)*), the inverse of the Sharpe ratio (*Bid/ SD(Bid)*), and the *payback* period in years.

Table 6.9: Example of a reinsurance treaty covering property damage risks

Year	Layer	Treaty's characteristics			Numbers of:			Information on the quotations				
		Limit xs Priority (M)	Recovery	GNPI (M)	Obs.	Reinsurer	Bids	Ln(RoL)	Bid (M)	SD(Bid)	SD(Bid)/Bid	Payback
2005	1	10 xs 5 (aad =15)	4 free. 1 at 50%	1.62	8	7	5	7.07	12.66	5.11	0.40	14
	2	15 xs 15	2 at 100%	1.62	8	8	6	6.04	6.45	1.60	0.25	17
	3	25 xs 30	1 at 100%	1.62	8	8	7	4.96	4.05	2.29	0.56	20
	4	20 xs 55	1 at 100%	1.62	8	8	7	4.13	1.50	0.96	0.64	24
	5	40 xs 75	1 at 100%	1.62	8	8	7	3.48	1.39	0.59	0.43	29
2006	1	10 xs 5 (aad =15)	4 free. 1 at 50%	1.67	9	9	4	6.63	8.30	3.81	0.46	15
	2	15 xs 15	2 at 100%	1.67	10	10	5	5.89	5.45	0.38	0.07	17
	3	25 xs 30	1 at 100%	1.67	9	9	7	4.78	3.13	1.11	0.35	21
	4	20 xs 55	1 at 100%	1.67	9	9	6	3.69	0.87	0.40	0.46	27
	5	40 xs 75	1 at 100%	1.67	9	9	6	3.20	1.00	0.25	0.25	31
2007	1	10 xs 5 (aad =15)	4 free. 1 at 50%	1.66	14	12	5	7.06	11.90	2.54	0.21	14
	2	15 xs 15	2 at 100%	1.66	14	12	7	5.97	5.92	0.58	0.10	17
	3	25 xs 30	1 at 100%	1.66	14	12	8	4.57	2.43	0.30	0.12	22
	4	20 xs 55	1 at 100%	1.66	14	12	6	3.71	0.86	0.29	0.34	27
	5	40 xs 75	1 at 100%	1.66	14	12	6	3.16	0.95	0.14	0.15	32
2008	1	10 xs 5 (aad =15)	4 free. 1 at 50%	1.72	14	12	6	6.91	10.13	1.85	0.18	14
	2	15 xs 15	2 at 100%	1.72	14	12	7	5.90	5.47	0.33	0.06	17
	3	25 xs 30	1 at 100%	1.72	14	12	8	4.49	2.25	0.30	0.13	22
	4	20 xs 55	1 at 100%	1.72	14	12	8	3.45	0.65	0.16	0.25	29
	5	40 xs 75	1 at 100%	1.72	14	12	6	3.07	0.87	0.08	0.10	33
2009	1	10 xs 5 (aad =15)	4 free. 1 at 50%	-	11	11	4	7.14	13.02	3.92	0.30	14
	2	15 xs 15	2 at 100%	-	11	11	6	5.94	5.72	0.47	0.08	17
	3	25 xs 30	1 at 100%	-	12	11	7	4.57	2.49	0.70	0.28	22
	4	20 xs 55	1 at 100%	-	12	11	7	3.51	0.70	0.22	0.31	29
	5	40 xs 75	1 at 100%	-	12	11	5	2.96	0.78	0.11	0.15	34
2010	1.3	10 xs 5 (aad =15)	4 free. 1 at 50%	-	10	9	6	6.98	11.13	3.08	0.28	14
	1.2	10 xs 5 (aad =15)	3 free. 2 at 50%	-	10	8	6	7.01	11.11	1.21	0.11	14
	1.1	10 xs 5 (aad=20)	4 free. 1 at 50%	-	10	10	6	7.24	14.00	1.93	0.14	14
	2	15 xs 15	2 at 100%	-	10	9	6	5.96	5.82	0.65	0.11	17
	3a	25 xs 30	none	-	10	8	3	4.23	1.80	0.57	0.43	22
	3b	25 xs 30	1 at 100%	-	10	9	6	4.46	2.33	0.99	0.32	24
	4a	20 xs 55	none	-	10	8	4	3.34	0.57	0.12	0.15	30
	4b	20 xs 55	1 at 100%	-	10	8	6	3.35	0.57	0.09	0.21	30
	5	40 xs 75	1 at 100%	-	10	8	5	2.75	0.69	0.25	0.37	36

Note: See previous page for explanations.

Table 6.10: Example of a reinsurance treaty covering motor risks

Year	Layer	Treaty's characteristics			Numbers of:			Information on the quotations				
		Limit xs Priority (M)	Recovery	GNPI (M)	Obs.	Reinsurer	Bids	Ln(RoL)	Bid (M)	SD(Bid)	SD(Bid)/Bid	Payback
2005	1	6 xs 1	1 free. 1 at 100%	129	3	3	3	4.87	0.58	0.16	0.28	21
	2	14 xs 7	1 free. 1 at 100%	129	3	3	2	2.97	0.20	0.05	0.23	34
	3	39 xs 21	1 free. 1 at 100%	129	3	3	2	0.94	0.11	0.11	1.05	06
2006	1	6 xs 1	1 free. 1 at 100%	157	3	3	3	4.98	0.67	0.32	0.48	20
	2	14 xs 7	1 free. 1 at 100%	157	3	3	3	3.13	0.23	0.05	0.22	32
	3	39 xs 21	1 free. 1 at 100%	157	3	3	3	0.82	0.10	0.11	1.13	122
2007	1	5 xs 2	2 free. 1 at 100%	175	3	3	3	4.51	0.30	0.11	0.35	22
	2	14 xs 7	1 free. 1 at 100%	175	3	3	2	3.11	0.20	0.00	0.00	32
	3	39 xs 21	1 free. 1 at 100%	175	3	3	2	0.30	0.03	0.00	0.00	336
2008	1	5 xs 2	2 free. 1 at 100%	205	4	4	4	4.46	0.27	0.07	0.27	22
	2	14 xs 7	1 free. 1 at 100%	205	4	4	3	2.67	0.13	0.05	0.38	37
	3	39 xs 21	1 free. 1 at 100%	205	4	4	3	0.42	0.04	0.00	0.06	238
2009	1	5 xs 2	2 free. 1 at 100%	212	6	6	3	4.39	0.32	0.01	0.04	23
	2	14 xs 7	1 free. 1 at 100%	212	6	6	1	2.90	0.20	-	0	34
	3	39 xs 21	1 free. 1 at 100%	212	6	6	1	0.49	0.05	-	0	205
2010	1.1	5 xs 2	2 free. 1 at 100%	230	7	7	5	4.83	0.52	0.31	0.59	21
	1.2	4 xs 3	2 free. 1 at 100%	230	7	7	5	4.37	0.29	0.22	0.77	23
	2	53 xs 7	2 free. 1 at 100%	230	7	7	4	1.58	0.23	0.15	0.67	63

Note: See 2 pages above for explanations.

Table 6.11: Example of a reinsurance treaty covering natural event risks (XL Cat treaty)

Year	Layer	Treaty's characteristics			Numbers of:			Information on the quotations				
		Limit xs Priority (M)	Recovery	GNPI (M)	Obs.	Reinsurer	Bids	Ln(RoL)	Bid (M)	SD(Bid)	SD(Bid)/Bid	Payback
2005	1	75 xs 50	1 at 100%	604	7	4	4	5.25	20.18	1.19	0.06	19
	2	125 xs 125	1 at 100%	604	7	4	4	4.37	14.02	0.76	0.05	23
	3	100 xs 250	1 at 100%	604	7	4	4	3.91	7.05	0.44	0.06	26
	4	100 xs 350	1 at 100%	604	7	4	4	3.61	5.25	0.60	0.11	28
	5	50 xs 450	1 at 100%	604	7	4	4	3.31	1.94	0.27	0.14	30
2006	1	75 xs 75	1 at 100%	658	6	5	5	5.18	19.54	2.71	0.14	19
	2	100 xs 150	1 at 100%	658	6	5	5	4.58	14.28	2.00	0.14	22
	3	100 xs 250	1 at 100%	658	6	5	5	4.16	9.38	1.23	0.13	24
	4	100 xs 350	1 at 100%	658	6	5	5	3.86	6.96	0.67	0.10	26
	5	100 xs 450	1 at 100%	658	6	5	5	3.60	5.29	0.73	0.14	28
2007	1	75 xs 125	1 at 100%	709	8	6	4	5.12	18.91	3.16	0.17	20
	2	150 xs 200	1 at 100%	709	8	6	4	4.65	23.50	2.93	0.12	21
	3	100 xs 350	1 at 100%	709	8	6	5	4.25	10.48	0.59	0.06	24
	4	100 xs 450	1 at 100%	709	8	6	5	4.02	8.29	0.86	0.10	25
	5	130 xs 550	1 at 100%	709	8	6	5	3.86	9.22	0.77	0.08	26
	6	90 xs 680	1 at 100%	709	8	6	5	3.68	5.32	0.45	0.08	27
2008	1	125 xs 125	1 at 100%	708	10	8	1	4.94	23.77	-	0	20
	2	250 xs 250	1 at 100%	708	10	8	2	4.39	27.54	1.51	0.05	23
	3	325 xs 500	1 at 100%	708	4	1	1	3.72	18.29	-	0	27
2009	1.1	150 xs 100	1 at 100%	687	9	5	2	5.21	28.31	2.03	0.07	19
	1.2	125 xs 125	1 at 100%	687	9	6	3	5.02	19.57	2.60	0.13	20
	2	250 xs 250	1 at 100%	687	9	6	3	4.41	21.29	1.23	0.06	23
	3	325 xs 500	1 at 100%	687	9	6	3	3.83	15.65	2.47	0.16	26
2010	1	50 xs 75	1 at 100%	619	1	1	1	5.43	12.86	-	0	18
	2	125 xs 125	1 at 100%	619	7	6	4	4.93	19.57	1.80	0.09	20
	1-2	150 xs 100	1 at 100%	619	7	6	1	5.07	26.75	-	0	20
	3a	250 xs 250	1 at 100%	619	7	6	5	4.32	21.15	1.78	0.08	23
	3b	300 xs 250	1 at 100%	619	7	6	4	4.26	23.87	2.14	0.09	23
	4a	330 xs 500	1 at 100%	619	7	6	5	3.69	14.61	1.04	0.07	27
	4b	275 xs 550	1 at 100%	619	7	6	4	3.68	12.25	1.01	0.08	27

Note: See 3 pages above for explanations.

Table 6.12: Bidding rate and probability across treaties with specific number of tranches

Total tranches in the treaty	**Average number of bids per reinsurer and treaty**		**Probability to bid on all the treaty's tranches**	
	nb	% of total tranches	% of observations	% of bidding reinsurers
1	0,60	60,0%	60,0%	100,0%
2	1,14	56,8%	54,4%	92,1%
3	1,69	56,3%	52,5%	88,1%
4	2,36	59,0%	52,1%	82,4%
5	2,73	54,5%	43,4%	71,1%
6	3,56	59,3%	39,3%	57,5%
7	3,56	50,9%	27,0%	41,3%
8	3,35	41,9%	25,3%	51,4%
9	4,78	53,1%	32,4%	44,7%
10	4,31	43,1%	21,0%	36,0%
11	5,09	46,3%	17,3%	21,0%
12	3,49	29,1%	9,3%	14,1%
13	6,16	47,4%	11,8%	12,3%
14	7,86	56,1%	0,0%	0,0%
16	4,03	25,2%	0,0%	0,0%
Total	2,38	54,6%	45,0%	72,8%

Note: The first column reports the average number of bids per reinsurer and per treaty with specific total number of tranches. The second column reports this number in percentage of the total number of tranches within the treaty, i.e. it is the average bidding rate per reinsurer and per treaty. The last two columns report the probability of bidding on the entire treaty, in percentage of all observations, and in percentage of only the reinsurers who quoted at least one layer of the treaty.

Table 6.13: Bid and rate-on-line according to the bidding rate

Total tranches in the treaty		**Bid**				**RoL (in log)**			
		Bidding on all	Bidding on more than half	Bidding on less than half	Total	Bidding on all	Bidding on more than half	Bidding on less than half	Total
1	*mean*	2,28			2,28	4,33			4,33
	sd	3,61			3,61	1,50			1,50
2	*mean*	1,51		5,09	1,69	4,21		4,22	4,21
	sd	2,95		10,81	3,84	1,66		1,69	1,66
3	*mean*	1,32	2,58	1,93	1,41	4,11	4,35	4,26	4,13
	sd	2,81	5,39	4,71	3,08	1,44	1,33	1,67	1,44
4	*mean*	1,68	2,23	3,05	1,79	4,25	4,32	4,60	4,27
	sd	3,09	3,66	4,40	3,23	1,36	1,30	1,22	1,35
5	*mean*	2,41	2,76	2,52	2,48	4,28	4,49	4,38	4,32
	sd	3,83	4,06	3,32	3,86	1,39	1,37	1,35	1,39
6	*mean*	3,95	6,01	14,26	5,16	4,46	4,44	4,46	4,45
	sd	10,43	11,36	16,52	11,38	1,62	1,23	1,92	1,53
7	*mean*	1,88	5,13	6,61	3,70	4,47	4,12	4,09	4,29
	sd	2,28	6,56	5,29	5,07	1,47	1,41	1,06	1,41
8	*mean*	1,96	2,93	3,72	2,40	3,87	3,87	4,05	3,88
	sd	2,05	1,73	0,99	1,97	0,99	0,88	0,70	0,94
9	*mean*	3,39	5,08	15,79	6,27	4,74	4,69	4,30	4,64
	sd	4,29	5,56	21,93	11,56	1,28	1,29	1,30	1,29
10	*mean*	12,31	15,92	18,83	14,93	4,42	4,34	4,29	4,37
	sd	10,63	16,58	15,79	14,35	0,70	0,65	0,55	0,65
11	*mean*	3,74	11,24	19,68	14,18	4,37	4,57	4,22	4,33
	sd	1,86	15,15	20,82	18,19	0,65	0,94	0,69	0,74
12	*mean*	15,97	10,51	21,26	17,87	4,45	4,13	4,43	4,37
	sd	14,64	13,16	19,14	17,56	0,71	0,60	0,62	0,65
13	*mean*	26,88	27,52	28,40	27,97	4,41	4,62	4,70	4,64
	sd	8,91	13,09	12,34	12,12	0,45	0,83	0,71	0,72
14	*mean*		1,29	0,98	1,24		5,59	4,75	5,45
	sd		0,80	0,54	0,76		1,31	1,35	1,34
16	*mean*			35,89	35,89			4,47	4,47
	sd			22,33	22,33			0,61	0,61
Total	*mean*	2,19	5,42	14,96	3,56	4,24	4,38	4,38	4,27
	sd	4,71	9,57	18,40	8,12	1,45	1,25	1,14	1,41

Note: The table displays the average bid, logarithm of the rate-on-line and the associated standard deviations according to the total number of tranches within the treaty and of the bidding rate. The Bidding rate has been divided into three categories: a bidding rate equal to one meaning that the reinsurer bids on all the layers' treaty; a bidding rate greater than 50%, meaning that the reinsurer bids on more than half of the layers' treaty; and a bidding rate equal or lower than 50% for the reinsurers who bid on less than half of the treaty.

Table 6.14: Bidding rate and probability across the major LoB

Major LoB	**Average number of bids per reinsurers and treaty** nb	% of total tranches	**Probability to bid on all the tranches' treaty** % of observations	% of bidding reinsurers
Natural cat.	2,71	0,44	29,4%	51,3%
Property damage	2,69	0,58	47,8%	75,6%
General liability	1,91	0,62	54,9%	81,0%
Accident	1,61	0,66	62,7%	93,6%
Motor liability	1,98	0,59	50,7%	78,4%
Transportation	2,57	0,65	56,6%	81,7%
Maritime	2,67	0,62	58,4%	93,4%
Total	2,49	0,54	56,2%	84,8%

Note: The first column reports the average number of bids per reinsurer and per treaty for each of the seven biggest LoB. The second column reports this number in percentage of the total number of tranches within the treaty, i.e. it is the average bidding rate per reinsurer and per treaty. The last two columns report the probability of bidding on the entire treaty, in percentage of all observations, and in percentage of only the reinsurers who quoted at least one layer of the treaty.

Table 6.15: Frequency table of the lines of business across treaty with specific number of tranches

Major LoB	**Nb of obs. per tranche**	**Nb of layers per treaty**	**Total tranches in the treaties** 1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	Total
Natural cat.	8,60	3,31	28	36	24	27	23	8	7	7	3	4	3	3	1	0	1	175
Property damage	6,91	2,36	31	22	45	34	19	16	3	0	3	0	0	0	0	1	0	174
General liability	5,85	1,90	36	26	33	13	8	0	1	0	0	0	0	0	0	0	0	117
Accident	5,61	1,69	32	31	25	2	2	0	0	0	0	0	0	0	0	0	0	92
Motor liability	6,97	2,03	29	14	21	5	7	1	2	0	0	0	0	0	0	0	0	79
Transportation	4,42	2,27	17	8	23	14	12	3	0	0	0	0	0	0	0	0	0	77
Maritime	4,84	2,37	13	18	7	14	7	1	1	2	1	0	1	0	0	0	0	65
Total	6,17	2,59	186	155	178	109	78	29	14	9	7	4	4	3	1	1	1	779

Note: The table displays the distribution of the tranches and treaties over the the seven biggest LoB of the data-set. It reports the number of observation on the LoB in the data-set, the average number of layers in the treaties on this LoB, and the number of treaties according to their total number of tranches.

Table 6.16: Bid and rate-on-line per tranche scale across time

Tranche scale		Bid							RoL (in log)						
		2005	2006	2007	2008	2009	2010	Total	2005	2006	2007	2008	2009	2010	Total
One tranche	*mean*	1,80	2,11	3,05	1,69	2,71	2,25	2,28	4,31	4,60	4,21	4,19	4,23	4,45	4,33
	sd	2,89	2,76	5,09	3,07	3,99	3,04	3,61	1,55	1,54	1,38	1,70	1,43	1,41	1,50
Low layers	*mean*	2,58	5,82	3,11	7,49	6,22	5,39	5,12	5,14	5,37	5,35	5,16	5,20	5,26	5,26
	sd	6,00	10,20	4,70	13,86	14,65	12,73	11,28	1,34	1,19	0,97	0,85	1,16	1,00	1,07
Middle layers	*mean*	2,17	6,08	3,60	3,88	4,01	3,33	3,87	4,33	4,30	4,22	4,34	4,26	4,14	4,25
	sd	2,90	10,34	8,59	5,50	8,01	7,41	7,87	0,99	1,06	1,06	1,00	1,26	0,95	1,07
Top layers	*mean*	1,12	1,50	2,02	2,39	1,78	1,65	1,81	3,03	3,14	3,20	3,29	3,13	3,23	3,18
	sd	1,70	2,23	4,19	3,68	3,33	3,17	3,33	1,84	1,25	1,08	0,97	1,17	1,28	1,24
Total	*mean*	1,92	4,30	3,00	4,20	3,99	3,54	3,56	4,16	4,29	4,32	4,22	4,24	4,33	4,27
	sd	3,85	8,46	6,32	8,55	9,74	8,89	8,12	1,67	1,48	1,34	1,27	1,45	1,35	1,41

Note: The table displays the average bid, logarithm of the rate-on-line and the associated standard deviations, as well as the frequencies, according to the level of the tranche within the treaty for the six years spanned by the data-set.

Table 6.17: Bid and rate-on-line per tranche scale for the three major LoB

Tranches scale		Bid				RoL (in log)			
		Property damage	General liability	Natural catastrophe	Total	Property damage	General liability	Natural catastrophe	Total
One tranche	*mean*	1,23	2,54	6,08	3,06	4,14	4,83	4,15	4,45
	sd	2,88	2,77	6,78	4,60	1,06	1,49	1,16	1,33
Low layers	*mean*	2,31	3,82	13,90	7,51	5,53	5,29	4,99	5,26
	sd	3,42	6,36	18,74	13,85	0,91	1,46	0,65	0,97
Middle layers	*mean*	1,44	1,91	9,99	5,40	4,40	4,01	4,26	4,29
	sd	1,43	2,45	12,17	9,32	0,96	1,50	0,82	0,99
Top layers	*mean*	0,60	0,93	4,53	2,61	3,22	3,09	3,54	3,36
	sd	0,52	1,41	4,80	3,94	0,59	1,52	0,76	0,90
Total	*mean*	1,51	2,37	9,40	5,20	4,47	4,29	4,26	4,35
	sd	2,32	4,25	13,48	10,06	1,23	1,73	0,95	1,22

Note: The table displays the average bid, logarithm of the rate-on-line and the associated standard deviations, as well as the frequencies, according to the level of the tranche within the treaty for the three major LoB of the data-set.

Table 6.18: Bid and rate-on-line per reinsurer size group across time

Reinsurer size		Bid							RoL (in log)						
		2005	2006	2007	2008	2009	2010	Total	2005	2006	2007	2008	2009	2010	Total
Big reinsurers	*mean*	1,95	3,18	2,47	3,37	3,45	2,97	2,90	4,15	4,21	4,29	4,19	4,25	4,28	4,24
	sd	4,29	6,68	5,06	7,21	8,99	6,75	6,75	1,74	1,59	1,39	1,33	1,54	1,48	1,48
	freq	612	765	1 398	818	909	963	5 465							
Medium reinsurers	*mean*	1,84	4,95	3,64	4,45	4,27	3,24	3,84	4,14	4,37	4,33	4,25	4,24	4,36	4,30
	sd	2,89	9,16	7,85	8,85	9,38	8,36	8,36	1,57	1,39	1,32	1,20	1,31	1,33	1,33
	freq	328	604	819	649	867	1 072	4 339							
Small reinsurers	*mean*	2,17	8,84	3,82	7,14	5,02	6,14	5,63	4,34	4,44	4,44	4,23	4,19	4,35	4,33
	sd	3,75	13,04	6,76	11,89	13,13	11,91	11,91	1,42	1,14	1,10	1,25	1,60	1,33	1,33
	freq	46	103	255	176	240	331	1 151							
Total	*mean*	1,92	4,30	3,00	4,20	3,99	3,54	3,56	4,16	4,29	4,32	4,22	4,24	4,33	4,27
	sd	3,85	8,46	6,32	8,55	9,74	8,12	8,12	1,67	1,48	1,34	1,27	1,45	1,41	1,41
	freq	986	1 472	2 472	1 643	2 016	2 366	10 955							

Note: The table displays the average bid, logarithm of the rate-on-line and the associated standard deviations, as well as the frequencies, according to the reinsurer's size for the six years spanned by the data-set. The big reinsurers regroup the four biggest reinsurers of the data-set, the medium reinsurers the 13 following, and the small reinsurers the 42 last.

Table 6.19: Bid and rate-on-line per reinsurer size group for the three major LoB

Reinsurer size		Bid				RoL (in log)			
		Property damage	General liability	Natural catastrophe	Total	Property damage	General liability	Natural catastrophe	Total
Big reinsurers	*mean*	1,39	2,09	7,59	4,01	4,46	4,21	4,26	4,32
	sd	2,05	3,72	11,83	8,31	1,19	1,81	1,02	1,29
	freq	1 281	702	1 320	3 303				
Medium reinsurers	*mean*	1,80	2,87	10,06	5,72	4,46	4,39	4,29	4,37
	sd	2,74	4,91	13,68	10,39	1,27	1,55	0,87	1,15
	freq	1 047	325	1 161	2 533				
Small reinsurers	*mean*	0,76	3,68	12,99	8,94	4,57	5,23	4,19	4,35
	sd	0,87	6,67	16,35	14,49	1,21	1,39	0,95	1,09
	freq	203	31	451	685				
Total	*mean*	1,51	2,37	9,40	5,20	4,47	4,29	4,26	4,35
	sd	2,32	4,25	13,48	10,06	1,23	1,73	0,95	1,22
	freq	2 531	1 058	2 932	6 521				

Note: The table displays the average bid, logarithm of the rate-on-line and the associated standard deviations, as well as the frequencies, according to the reinsurer's size for the three major LoB of the data-set.

Table 6.20: Bidding rate and all treaty probability per reinsurer size group

	Average number of bids per reinsurer and treaty		**Probability to bid on all the treaty's tranches**	
Reinsurer size group	nb	% of total tranches	% of observations	% of bidding reinsurers
Big reinsurers	2,83	66,2%	57,1%	79,7%
Medium reinsurers	2,21	50,2%	40,5%	70,3%
Small reinsurers	1,72	36,4%	25,6%	52,0%
Total	2,39	54,9%	45,0%	72,8%

Note: The first column reports the average number of bids per reinsurer for each group of reinsurers. The second column reports this number in percentage of the total number of tranches within the treaty, i.e. it is the average bidding rate per reinsurer and per treaty. The last two columns report the probability of bidding on the entire treaty, in percentage of all observations, and in percentage of only the reinsurers who quoted at least one layer of the treaty.

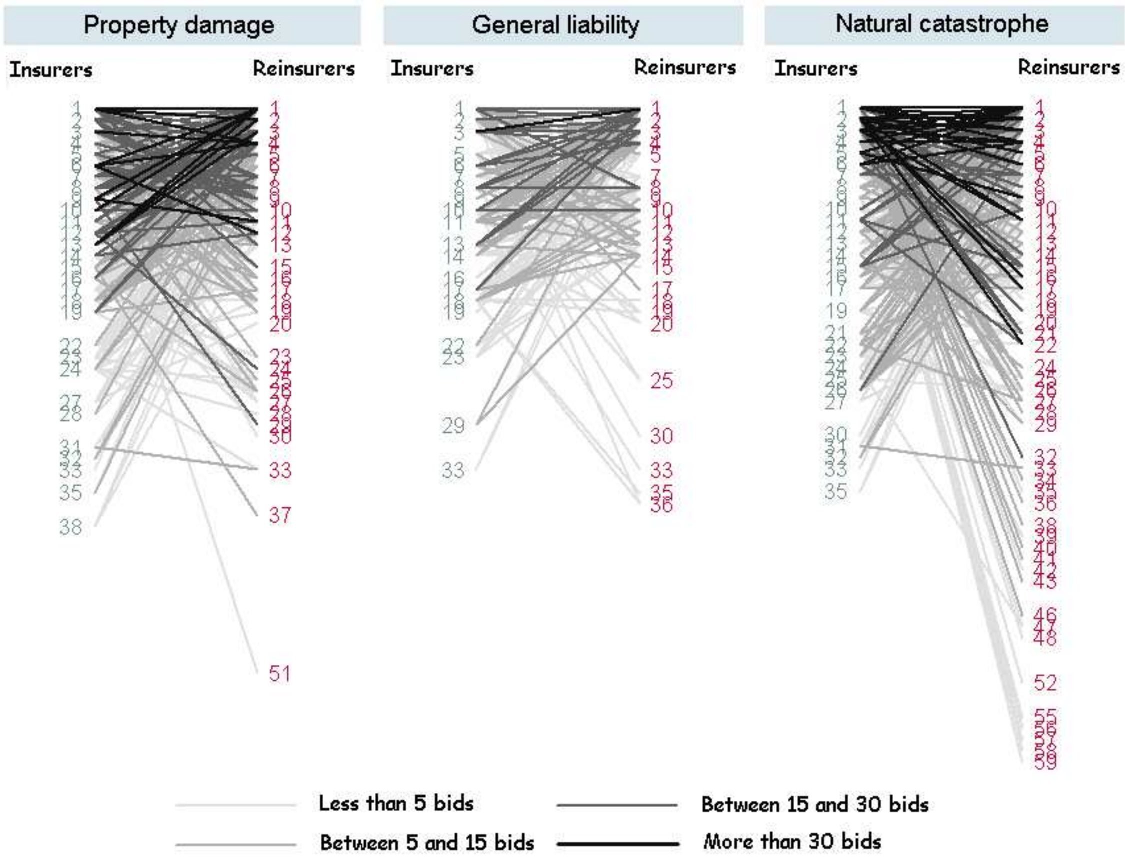

Figure 6.8: Network graph of the connections between insurers and reinsurers from the number of bids

Note: This figure displays the paired insurers and reinsurers according to the number of bids the reinsurer offers to the insurer. The insurers and reinsurers have been ranked according to their appearance in the data-set.

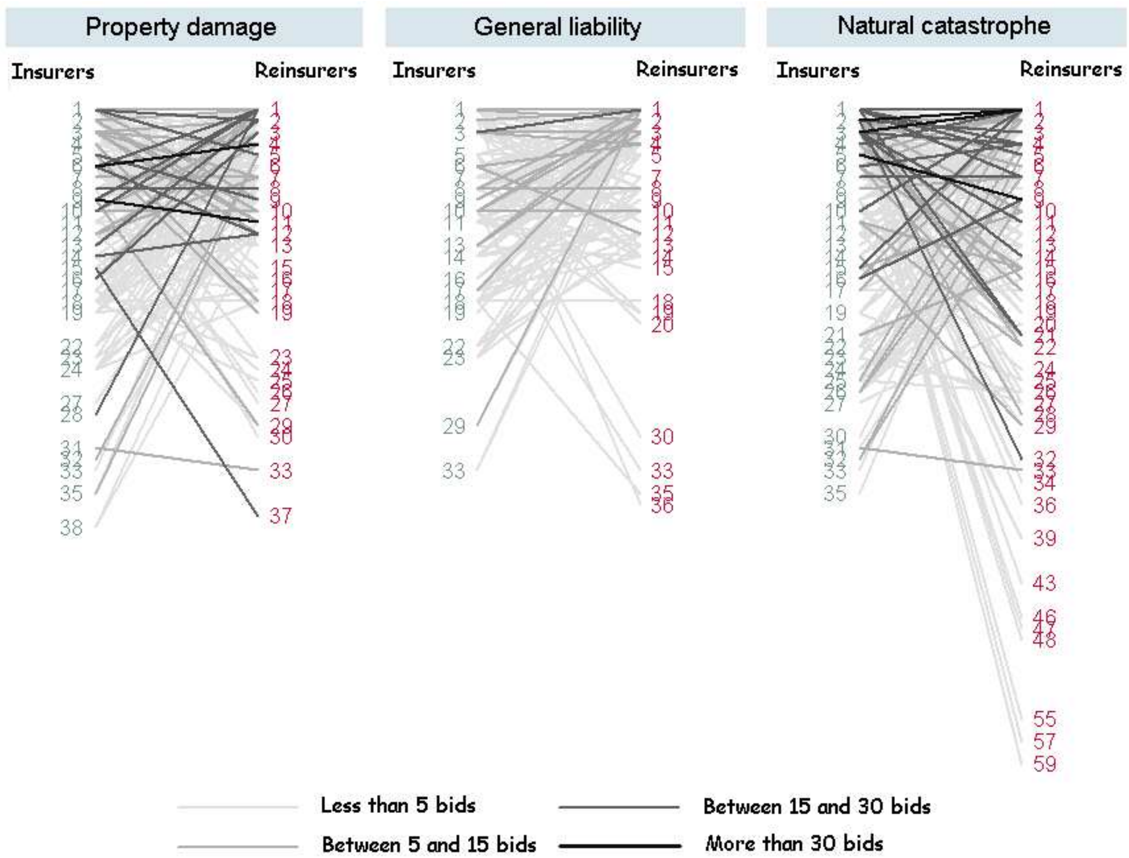

Figure 6.9: Network graph of the connections between insurers and reinsurers from the number of lowest bids

Note: This figure displays the paired insurers and reinsurers according to the number of lowest bids the reinsurer offers to the insurer. The insurers and reinsurers have been ranked according to their appearance in the data-set.

Table 6.21: Lowest bid and rate-on-line per reinsurer size group across time

Reinsurer size		Bid							RoL (in log)						
		2005	2006	2007	2008	2009	2010	Total	2005	2006	2007	2008	2009	2010	Total
Big reinsurers	*mean*	1,30	1,75	1,74	2,53	2,48	2,43	2,05	3,61	3,75	3,96	3,77	3,94	3,93	3,85
	sd	2,10	3,51	3,94	6,18	4,45	5,04	4,41	2,34	1,82	1,51	1,30	1,51	1,35	1,63
	freq	179	209	375	201	278	262	1 504							
Medium reinsurers	*mean*	1,75	1,95	1,96	2,70	2,66	2,27	2,26	3,84	3,97	4,09	3,96	3,87	4,03	3,97
	sd	2,64	4,75	4,12	6,08	6,23	6,63	5,50	1,86	1,44	1,45	1,28	1,42	1,43	1,46
	freq	120	176	243	173	282	281	1 275							
Small reinsurers	*mean*	2,30	4,82	2,97	3,35	3,22	8,18	4,67	4,02	4,54	4,33	3,95	4,18	4,05	4,16
	sd	2,75	5,70	4,99	3,87	10,33	17,09	11,37	1,30	0,94	1,16	1,61	1,68	1,34	1,43
	freq	15	20	84	51	118	118	406							
Total	*mean*	1,52	1,99	1,97	2,70	2,68	3,39	2,47	3,72	3,88	4,05	3,87	3,96	3,99	3,94
	sd	2,36	4,25	4,15	5,90	6,54	9,25	6,20	2,13	1,64	1,46	1,33	1,51	1,38	1,54
	freq	314	405	702	425	678	661	3 185							

Note: The table displays the average of the lowest bids, of the logarithm of the rate-on-lines and of the associated standard deviations, as well as the frequencies, according to the reinsurer's size for the six years spanned by the data-set.

Table 6.22: Lowest bid and rate-on-line per reinsurer size group for the three major LoB

Reinsurer size		Bid				RoL (in log)			
		Property damage	General liability	Natural catastrophe	Total	Property damage	General liability	Natural catastrophe	Total
Big reinsurers	*mean*	1,38	1,54	5,22	2,85	4,27	3,74	3,88	3,99
	sd	2,74	3,00	7,59	5,46	1,26	1,91	1,03	1,40
	freq	325	215	320	860				
Medium reinsurers	*mean*	1,24	2,02	5,64	3,37	4,06	3,80	4,08	4,04
	sd	2,08	3,62	9,73	7,18	1,29	1,78	0,94	1,23
	freq	273	89	310	672				
Small reinsurers	*mean*	0,57	1,41	10,51	7,33	4,45	5,31	4,06	4,23
	sd	0,81	0,68	16,10	14,01	1,25	1,58	1,02	1,15
	freq	67	12	165	244				
Total	*mean*	1,24	1,67	6,48	3,66	4,20	3,82	3,99	4,04
	sd	2,36	3,14	10,85	7,94	1,28	1,88	1,00	1,31
	freq	665	316	795	1 776				

Note: The table displays the average of the lowest bids, of the logarithm of the rate-on-lines and of the associated standard deviations, as well as the frequencies, according to the reinsurer's size for the three major LoB of the data-set.

Table 6.23: Biddings per reinsurer and per treaty per reinsurer size group over time

	Average number							**Bidding rate (% of total tranches)**						
Reinsurer size group	2005	2006	2007	2008	2009	2010	Total	2005	2006	2007	2008	2009	2010	Total
Big reinsurers	2,37	2,92	3,17	2,98	2,71	2,62	2,83	72,9%	74,6%	69,7%	69,8%	58,4%	58,1%	66,2%
Medium reinsurers	1,84	3,10	2,34	2,32	2,32	2,18	2,33	52,7%	69,5%	49,0%	50,3%	47,1%	46,0%	50,2%
Small reinsurers	1,16	1,47	2,64	1,66	1,49	1,61	1,73	42,2%	36,5%	51,4%	32,5%	34,6%	31,7%	36,4%
Total	2,07	2,83	2,75	2,47	2,32	2,21	2,44	62,8%	68,3%	58,7%	55,1%	49,1%	47,1%	54,6%

Note: The left side of the table reports the average number of bids per reinsurer and per treaty according to the reinsurer size group over time. The right side of the table reports these numbers in percentage of the total number of tranches within the treaty, i.e. it is the average bidding rate per reinsurer and per treaty.

Table 6.24: Probability to bid on all the treaty's tranches per reinsurer size group over time

	% of observations							**% of bidding reinsurers**						
Reinsurer size group	2005	2006	2007	2008	2009	2010	Total	2005	2006	2007	2008	2009	2010	Total
Big reinsurers	67,0%	67,3%	57,2%	59,4%	48,6%	52,2%	57,1%	88,4%	84,6%	74,8%	79,2%	74,9%	82,9%	79,7%
Medium reinsurers	45,1%	56,0%	39,2%	42,7%	36,0%	37,1%	40,5%	78,3%	70,5%	73,0%	75,9%	63,3%	68,9%	70,3%
Small reinsurers	35,8%	29,6%	33,9%	21,3%	25,5%	21,9%	25,6%	72,2%	57,3%	53,2%	46,7%	54,3%	48,5%	52,0%
Total	56,2%	58,6%	46,8%	45,8%	38,9%	39,0%	45,0%	84,2%	76,8%	72,0%	74,0%	67,0%	71,0%	72,8%

Note: The left side of the table reports the probability of bidding on the entire treaty in percentage of all observations, according to the reinsurer size group over time. The right side of the table reports this probability in percentage of only the reinsurers who quoted at least one layer of the treaty.

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