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Pierre Trupin

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THÈSE DE DOCTORAT

DE L'UNIVERSITÉ PSL

Préparée à l'Université Paris-Dauphine

**Études de l'influence des mécanismes de gouvernement
d'entreprise sur la politique d'innovation : structure
actionnariale, conseil d'administration et créanciers**

Soutenue par

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L'Université Paris-Dauphine n'entend donner aucune approbation, ni improbation aux opinions émises dans cette thèse ; elles doivent être considérées comme propres à leur auteur.

Remerciements

Si la thèse est un travail qui se vit en solitaire, son aboutissement est le résultat de la contribution de plusieurs personnes. Ces quelques lignes leur sont destinées.

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Introduction générale

1. Contexte de la recherche

Face à un environnement en constante évolution, notamment d'un point de vue réglementaire ou technologique, les entreprises sont contraintes de s'adapter afin de conserver un avantage compétitif (Porter, 1992). L'innovation semble être l'un des moyens pour y parvenir.

Il semble alors légitime de s'interroger sur les moyens dont disposent les entreprises pour y parvenir. Si les déterminants de l'innovation ont fait l'objet de nombreuses études, notre compréhension reste toutefois limitée. L'objet de cette thèse est alors de contribuer à ce champ de recherche en étudiant le rôle des mécanismes de gouvernement d'entreprise sur la politique d'innovation.

Largement mentionnée et manipulée dans diverses disciplines, l'innovation est un concept polymorphe. Selon Schumpeter (1934), l'innovation peut prendre la forme d'un nouveau produit, d'une nouvelle forme d'organisation ou encore d'un nouveau procédé de production. *The Oxford Handbook of Innovation* (2006) donne une définition globale du concept comme étant la transformation et l'application d'une invention grâce à la combinaison de compétences, de ressources et de connaissances¹. Elle est donc différente de l'invention par son caractère opérationnel et sa mise en œuvre concrète.

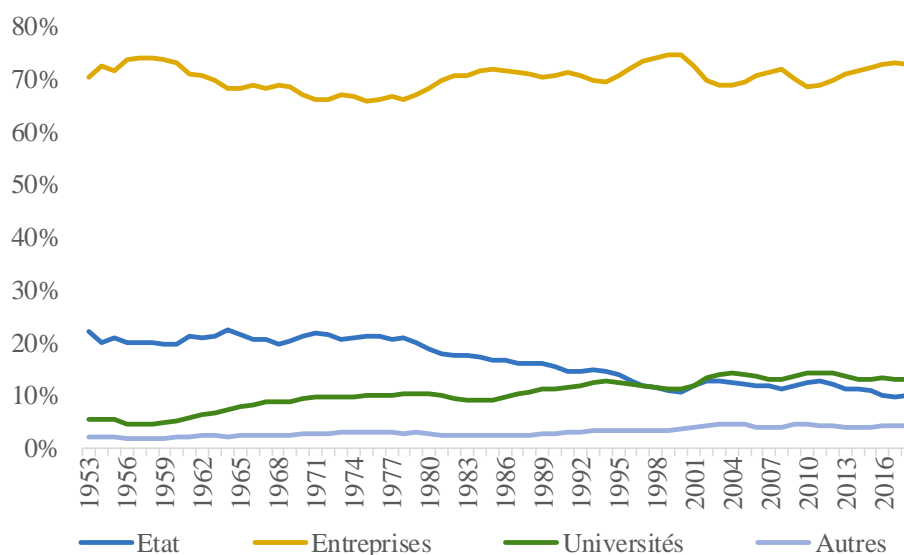
Si elle est principalement connue sous la forme de son résultat, par exemple le nouveau produit, l'innovation est avant tout l'accomplissement d'un processus, s'articulant autour d'opérations permettant d'obtenir un résultat : la recherche et la conception d'idées nouvelles, leur développement, et leur mise en production. Ce processus d'innovation n'est pas linéaire et l'obtention d'un résultat est incertain dans la mesure où toute recherche ne résulte pas forcément en un nouveau produit qui sera mis sur le marché. L'innovation est alors à la fois un résultat et un processus nouveaux comme l'indique le manuel d'Oslo (OCDE, 2018).

¹ Citation originale tirée de *The Oxford Handbook of Innovation*, 2006, p. 5 : "An important distinction is normally made between invention and innovation. Invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice. [...] To be able to turn an invention into an innovation, a firm normally needs to combine several different types of knowledge, capabilities, skills and resources."

Au niveau macroéconomique, l'innovation est synonyme de croissance (Solow, 1956 ; Arrow, 1962 ; Lucas, 1988 ; Romer, 1986). Il en est de même au niveau microéconomique : le développement de nouveaux produits et services ainsi que l'amélioration de son système de production permet à l'entreprise de jouir de nouveaux marchés et revenus mais aussi de dégager de meilleures marges. Ainsi, d'un point de vue financier, l'innovation permet donc de créer de la valeur (Abrams *et al.*, 2013 ; Hall *et al.*, 2005 ; Kogan *et al.*, 2017 ; Moser *et al.*, 2015).

Les entreprises ont intégré l'enjeu de l'innovation comme en attestent les graphiques ci-dessous. Aux Etats-Unis, les entreprises privées sont à l'origine d'environ 70% des dépenses en recherche et développement (Graphique 0.1) et de 90% des brevets déposés (Graphique 0.2) sur l'ensemble du territoire.

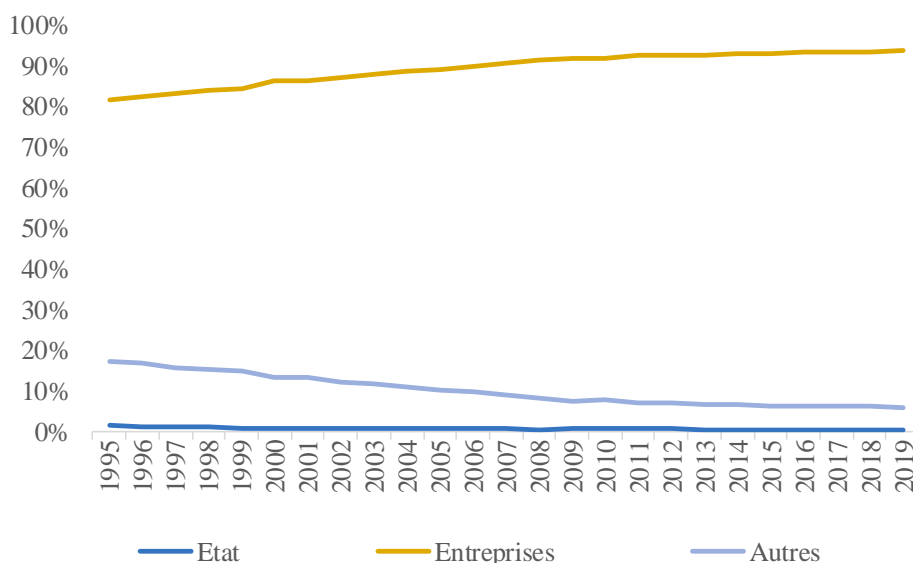
Graphique 0.1 : Répartition des dépenses en R&D aux États-Unis



Source : National Center for Science and Engineering Statistics, National Patterns of R&D Resources

Notes: Les données présentées sont calculées en USD constant de l'année 2012. La catégorie "Autres" correspond aux dépenses de R&D réalisées par des associations à but non lucratif

Graphique 0.2 : Répartition des brevets déposés aux États-Unis



Source : USPTO

Note: la catégorie "Autres" correspond aux brevets déposés par des particuliers

Face à l'enjeu que représente l'innovation, il semble rationnel pour les entreprises de dédier une partie de leurs ressources à la production d'innovations. Les dépenses en R&D étant la « matière première » de l'innovation, les entreprises ont intérêt à maximiser ces dépenses afin de pouvoir innover et créer de la valeur. Cette logique se heurte cependant à la réalité.

Les entreprises sont des « nœuds de contrats », selon la terminologie de Michael Jensen², et constituent le lieu où s'affrontent les intérêts des différentes parties prenantes. Dès lors, la définition de la politique d'innovation, régissant l'orientation des projets d'innovation et l'allocation des ressources, n'est pas uniquement du ressort des cadres dirigeants de l'entreprise. Au contraire, elle implique l'ensemble des parties prenantes de l'entreprise (actionnaires, créanciers, employés, etc.) dont les objectifs, attentes et visions peuvent être divergents. La politique d'innovation semble alors être régie par un système de relations au sein de l'entreprise.

² Citation originale tirée de Jensen & Meckling, *Theory of the Firm: Managerial Behavior, Agency Costs, and Ownership Structure*, 1976, p. 311 : "The private corporation or firm is simply one form of fiction which serves as a nexus for contracting relationships and which is also characterized by the existence of divisible residual claims on the assets and cash flows of the organization which can generally be sold without permission of the other contracting individuals."

La littérature qui s'est attachée à étudier ces relations renvoie au concept de gouvernement d'entreprise qui se définit comme l'ensemble des règles et pratiques qui permettent à une firme d'être dirigée. Le concept de gouvernement d'entreprise étudie notamment les mécanismes par lesquels les parties prenantes peuvent exercer leur influence : structure actionnariale, l'activisme actionnarial, la composition des conseils d'administration, etc. En répondant à des intérêts qui leur sont propres, les différentes parties prenantes de l'entreprise peuvent influencer les décisions stratégiques et opérationnelles et notamment la politique d'innovation. L'objectif de cette thèse est alors d'identifier et de comprendre les mécanismes de gouvernement d'entreprise pouvant influencer la politique d'innovation.

2. Problématique et questions de recherche

D'un point de vue financier, les projets d'innovation comportent des particularités qui les différencient d'autres types d'investissement.

Premièrement, l'investissement en innovation est caractérisé par une forte incertitude. Dans chaque projet d'innovation, la probabilité d'obtenir un résultat ainsi que la forme du résultat sont inconnues (Kerr et Nanda, 2015).

Deuxièmement, il apparaît que la distribution des rendements des projets d'innovation est très asymétrique : de nombreux projets engendrent de faibles rendements, proches de zéro, tandis qu'une infime partie de projets génère d'importants rendements. L'innovation se caractérise donc par de nombreux échecs, dont l'impact est faible, et peu de succès dont l'impact peut être grand (Scherer et Harhoff, 2000).

Troisièmement, l'innovation est empreinte d'asymétrie d'information dans la mesure où l'inventeur en sait plus que les investisseurs quant au projet d'innovation. À cela s'ajoute l'impossibilité de créer des contrats parfaits permettant la protection des investisseurs en cas de faillite d'un projet d'innovation (Aghion et Tirole, 1994 ; Hart et Moore, 1990).

Enfin, l'innovation en entreprise est caractérisée par un montant significatif d'actifs incorporels. Notamment, l'innovation est en majeure partie le résultat de connaissances acquises par un groupe d'individus ayant participé au projet. Le capital humain accumulé au cours de ces projets se déprécie avec le départ de membres de l'équipe, jusqu'à disparaître si les équipes sont modifiées de manière importante (Hall et Lerner, 2010).

L'ensemble de ces caractéristiques rend difficile l'évaluation d'un projet d'innovation par un membre extérieur au projet. Tant le dirigeant d'entreprise que le créancier et l'actionnaire prennent un risque en choisissant d'investir dans de tels projets.

Néanmoins, les parties prenantes de l'entreprise sont des acteurs de la politique d'innovation en raison de l'importance de celle-ci pour l'entreprise. La manifestation de leur intérêt propre peut impacter la politique d'innovation. En voici quelques illustrations :

- L'actionnaire caractérisé par des attentes à long terme serait favorable à l'innovation. Au contraire, celui ayant une vision à court terme serait défavorable à la mobilisation de ressources aujourd'hui pour un résultat incertain dans le futur (Aghion *et al.*, 2013; Bushee, 2001, 1998) ;
- Le dirigeant choisit les orientations stratégiques de l'entreprise ainsi que l'allocation des ressources au sein de l'entreprise et peut choisir de favoriser les départements R&D ou non. Son comportement, son aversion au risque, son enracinement sont aussi des caractéristiques influençant l'innovation au sein de l'entreprise (Holmstrom, 1989) ;
- Le créancier ne bénéficie pas de la création de valeur induite par l'investissement en innovation. Ainsi, cet agent aurait tendance à limiter le nombre de projets d'innovation. En effet ces projets pourraient impacter à la baisse la performance de l'entreprise jusqu'à la faillite, mettant à risque le remboursement du capital prêté.

Ces éléments donnent lieu à un cadre d'analyse particulièrement riche et intéressant pour notre recherche doctorale. Ainsi, le concept de gouvernement d'entreprise semble être une bonne clé de lecture pour comprendre les déterminants de la politique d'innovation. Cette thèse se propose donc de répondre à la problématique de recherche suivante:

Quels mécanismes de gouvernement d'entreprise permettent d'influencer la politique d'innovation ?

Nous proposons de décliner cette problématique en trois questions de recherche distinctes afin d'étudier trois mécanismes pouvant influencer la politique d'innovation de l'entreprise. Dans un premier temps nous étudions en quoi la structure actionnariale peut influencer le choix de processus d'innovation. Par la suite nous analysons comment la composition du conseil d'administration impacte la politique d'innovation. Enfin, nous établissons dans quelle mesure le recours à différents instruments de dette émis sur les marchés financiers peut influencer la politique d'innovation. Nous introduisons ces questions de recherche dans les prochaines sous-sections.

Dans la suite de cette thèse, nous prenons le parti d'analyser la politique d'innovation de l'entreprise selon deux éléments. Dans un premier temps nous nous attachons à étudier le choix en matière de processus d'innovation. Dans un second temps nous étudions le succès de la politique d'innovation en nous appuyant sur le nombre de brevets déposés et le nombre de citations reçues. Ces deux éléments permettent de mesurer le succès des politiques d'innovation par le volume ainsi que par sa qualité, un brevet recevant de nombreuses citations témoigne de l'importance de sa contribution.

2.1. Structure actionnariale et processus d'innovation ouverte

Depuis l'illustration de la divergence d'intérêts entre propriétaires et gestionnaires de l'entreprise par Bearle et Means (1932), l'étude de la structure actionnariale comme déterminant dans la relation d'agence a fait l'objet de nombreux articles académiques. La structure actionnariale influence le contrôle du dirigeant de l'entreprise en fonction de deux caractéristiques: la proportion du capital détenu (Shleifer et Vishny, 1986 ; Cronqvist et Fahlenbrach, 2009) et le type de gestion de portefeuille (Grossman et Hart, 1988).

Plus un actionnaire détient une part conséquente du capital de l'entreprise, plus il est incité à s'investir dans les activités de contrôle des dirigeants de l'entreprise et à prendre des initiatives en la matière. D'autre part, plus un investisseur est actif dans la gestion de son portefeuille, plus il sera à même de prendre part aux activités de contrôle de l'entreprise. A l'inverse, un investisseur se contentant de prendre des participations en fonction de la présence ou non d'entreprises au sein d'un indice serait moins incité à participer dans le contrôle des dirigeants.

La littérature s'est penchée sur le rôle des actionnaires dans la politique d'innovation des entreprises et démontre leur aptitude à influencer les politiques d'innovation selon leur poids dans la structure capitalistique ou leurs intentions. Par exemple, les investisseurs institutionnels, dont les objectifs de long terme sont avérés, favorisent l'expansion d'activité d'innovation. Cependant, au sein de cette même catégorie d'investisseurs se trouvent des actionnaires dits activistes dont l'objectif est de s'introduire dans la gouvernance de l'entreprise et d'orienter les décisions de manière à maximiser la valeur de l'entreprise rapidement. Ces actionnaires activistes peuvent avoir tendance à réduire les dépenses en recherche et développement afin de maximiser leur plus-value à court terme (Aghion *et al.*, 2013 ; Bushee, 2001, 1998).

Notre recherche se positionne dans ce corpus d'articles et s'en démarque par l'étude d'une politique d'innovation basée sur un modèle d' « innovation ouverte », caractérisé par la décentralisation des moyens de recherche de l'entreprise (Chesbrough, 2006). La littérature s'est concentrée sur la mesure de l'innovation à l'aide du montant de dépenses en R&D ou du nombre de brevets déposés et leurs citations. Cependant, ces variables ne représentent pas, à elles seules, l'innovation au sein des entreprises. Bien qu'elles présentent plusieurs avantages (facilement mesurables et disponibles publiquement), elles se concentrent sur le résultat de la politique d'innovation sans prendre en compte le processus.

Plus précisément, nous nous intéressons à la présence d'une structure de capital-risque d'entreprise au sein de l'entreprise. Le capital-risque d'entreprise (Corporate Venture Capital en anglais et abrégé par CVC par la suite), est un mode d'innovation hybride combinant à la fois des éléments externes et internes à l'entreprise. Selon Gompers et Lerner (1998), le CVC correspond à la pratique par les entreprises de prises de participations minoritaires au sein de petites sociétés au cœur de métier différent. L'objectif de ce type de structure est de pouvoir capter des informations concernant une technologie, un marché ou un produit en dehors des frontières de la firme dans le but de les développer en interne. En étant à l'interface de l'environnement interne et externe de l'entreprise, la pratique du CVC se distingue de la R&D (uniquement basée sur l'utilisation de ressources internes pour développer des innovations au sein de l'entreprise) et des fusions-acquisitions (dont l'objectif est d'aller chercher uniquement des ressources externes à l'entreprise pour innover).

Question de recherche 1 : Dans quelles mesures la structure actionnariale contribue-t-elle à la mise en place de politiques d'innovation ouverte ?

Cette question nous permet de mettre en évidence le rôle de certains types d'actionnaires dans la mise en place d'activités de CVC. Le cas échéant, quel est le mode opératoire de ces actionnaires ? Au-delà de l'identification d'une relation entre investisseur et émergence de CVC, cette question de recherche se propose d'analyser l'hétérogénéité des investisseurs et leur impact sur cette méthode d'innovation. Par ailleurs, cette problématique est abordée sous l'angle de la causalité. Nous appliquons alors la méthode des variables instrumentales en utilisant l'appartenance d'une entreprise à l'indice du S&P 500 comme instrument.

2.2. Composition du conseil d'administration et politique d'innovation

Dans le cadre de la relation d'agence entre le dirigeant de l'entreprise et les actionnaires (Jensen et Meckling, 1976), le conseil d'administration est un outil de contrôle de la société à disposition des actionnaires. Ces derniers, soucieux de maximiser la valeur de l'entreprise, élisent les administrateurs afin qu'ils défendent leurs intérêts. Les administrateurs dits « indépendants » (appelés *outsiders* dans la littérature) se voient endosser ce rôle de contrôle dans la mesure où ils ne sont pas liés de manière matérielle à l'entreprise au travers d'une rémunération indexée sur la performance de l'entreprise, telle que les stock-options (Weisbach et Hermalin, 1991). A l'inverse les *insiders* ne peuvent être indépendants dans la mesure où leur rémunération ainsi que leur succès au sein de l'entreprise est largement fonction de leur performance³.

De plus, le conseil d'administration assume le rôle de conseiller stratégique. Les administrateurs, par leurs compétences, expériences et réseaux, sont à même de diminuer les coûts de transactions auxquels font face les entreprises (Pfeffer et Salancik, 1978; Williamson, 1984) et donner les orientations stratégiques de la firme.

Selon la littérature, la composition du conseil d'administration serait à même d'influencer les politiques d'innovation mises en place au sein de l'entreprise, notamment en incitant les dirigeants ayant une aversion au risque à mettre en place des projets d'innovation (Balsmeier *et al.*, 2017 ; Lu et Wang, 2018) et en facilitant l'obtention d'informations (Faleye *et al.*, 2014). Le conseil d'administration serait alors à même de réduire l'incertitude caractérisant l'innovation.

Ces mécanismes s'opèrent via différentes composantes caractérisant le conseil d'administration. Notamment, les administrateurs contribuent à l'élaboration de la stratégie de l'entreprise grâce à leur expertise sectorielle, leurs expériences passées et leur réseau. C'est l'ensemble de ces éléments qui permet aux dirigeants d'avoir accès à des ressources afin de réduire l'incertitude et les coûts de transactions auxquels font face les entreprises.

³ Extrait de Hermalin & Weisbach, Boards of Directors as an Endogenously Determined Institution: a Survey of the Economic Literature, 2001, p. 2 : "Inside directors are employees or former employees of the firm. They generally are not thought to be independent of the CEO, since the success of their careers is often tied to the CEO's. Outside directors are not employees of the firm and usually do not have any business ties to the firm aside from their directorship. Outside directors are typically CEOs from other firms or prominent individuals in other fields."

Néanmoins, la littérature a analysé les différentes dimensions du conseil d'administration de manière distincte en se focalisant sur un seul type d'administrateur ou une seule dimension du rôle stratégique. La littérature ne semble donc pas intégrer les différentes fonctions du conseil d'administration. Nous tentons de pallier ce problème en analysant conjointement le rôle stratégique et de contrôle du conseil d'administration via l'étude de sa composition.

Question de recherche 2 : La politique d'innovation de l'entreprise est-elle fonction de la composition du conseil d'administration ?

Cette question de recherche nous permet de clairement identifier quelles sont les caractéristiques permettant d'influencer positivement l'innovation au sein des entreprises et si le caractère indépendant ou non de l'administrateur est déterminant.

2.3. Structure financière et succès de la politique d'innovation

En raison des différentes frictions qu'implique l'investissement en innovation (haut niveau d'incertitude, des rendements asymétriques et des problèmes d'agence), son évaluation par des investisseurs externes à l'entreprise est difficile. Cela peut freiner leur décision d'investir.

Néanmoins, les marchés financiers peuvent présenter une solution au financement de la politique d'innovation de l'entreprise. Ils facilitent l'allocation de capital entre les investisseurs et les entreprises innovantes (Rajan et Zingales, 1998). En effet, les investisseurs en capital et en dette sont intéressés par les hauts rendements que peuvent dégager de telles entreprises. Par ailleurs, ils sont à même d'influencer les politiques d'innovation en faisant interagir divers investisseurs aux objectifs différents (Akcigit and Kerr, 2018). Cela démontre l'influence que peut avoir la structure de capital sur les décisions d'investissement en matière d'innovation.

Puisqu'il existe une littérature abondante sur l'influence d'un financement par capitaux propres et la dette bancaire sur l'innovation en entreprise (Acharya and Xu, 2017 ; Brown *et al.*, 2009 ; Kerr and Nanda, 2015 ; Mann, 2018), nous choisissons d'analyser la composition de la dette d'une entreprise.

Plusieurs publications récentes permettent d'illustrer l'influence que cette caractéristique peut avoir sur la politique d'innovation (Chang *et al.*, 2019; Ma *et al.*, 2020). En particulier, Atanassov (2015) démontre une influence positive entre le ratio de dette obligataire et le succès de la politique d'innovation. Selon l'auteur, la dette obligataire implique une plus grande

tolérance au risque et flexibilité que la dette bancaire. L'impact positif d'un financement obligataire semble donc avéré.

Néanmoins, Aghion *et al.* (2004) démontrent que la relation entre le financement par dette et l'innovation au sein des entreprises est de forme concave. À mesure que les dépenses en R&D augmentent, les entreprises ont moins recours à l'emprunt. Cela incite à s'interroger sur l'intérêt de la dette obligataire lorsque l'entreprise cherche à financer des projets d'innovation conséquents.

Par ailleurs, il semble nécessaire de s'interroger sur la capacité de la dette levée sur les marchés financiers à influencer les entreprises dont l'investissement en innovation est sous-optimal. Les entreprises en situation de surendettement (*debt overhang* en anglais) pourraient refuser des opportunités d'innovation car elles sont incapables de contracter de la dette additionnelle. D'autre part, les entreprises proches du défaut⁴ font face à des situations de conflits entre actionnaires et créanciers qui impacte leur politique d'investissement. Les actionnaires ont intérêt à favoriser la prise de risque pouvant les amener à financer des projets non viables et donc surinvestir. Les créanciers, pour leur part, ont tendance à réduire le risque de l'entreprise et ne sont pas incités à investir dans des projets risqués, menant à un sous-investissement en innovation (Myers, 1977).

Ces éléments mettent en évidence la pertinence du rôle de la structure de financement sur la politique d'innovation, et nous incitent à poser la question de recherche suivante :

Question de recherche 3 : Dans quelle mesure la composition de la dette d'une entreprise influence-t-elle sa politique d'innovation ?

Nous répondons à cette question de recherche en étudiant l'influence de la dette obligataire et convertible sur la politique d'innovation. Dans un premier temps nous nous attachons à décrire comment évolue l'influence de la dette obligataire sur la politique d'innovation à mesure que le ratio de dette obligataire augmente. Cela nous permet d'identifier si la relation est de forme concave ou non. Dans un deuxième temps nous étudions les situations d'investissement sous-optimal en identifiant les entreprises en situation de surendettement et celles faisant face à des difficultés opérationnelles, synonyme de conflit entre actionnaires et créanciers.

⁴ Une entreprise est en situation de défaut lorsque la valeur de marché de ses actifs est inférieure à la valeur de ses dettes.

3. Description et analyse des littératures

Cette thèse se situe à l'interface de plusieurs littératures dans le domaine de l'économie de l'innovation et la finance d'entreprise. Notamment, nos analyses s'appuient sur la littérature de la structure actionnariale, les effets de la composition du conseil d'administration et la structure de financement des entreprises. Cette section nous permet de décrire les avancées de la recherche, de mettre en évidence les motivations de chaque partie prenante dans la gestion des opérations de l'entreprise et leur influence sur la politique d'innovation, et enfin, de positionner notre travail doctoral.

3.1. La structure actionnariale

La tendance à un actionnariat dispersé dans les entreprises cotées en fait un terreau favorable à la priorisation des intérêts privés des dirigeants avant la maximisation de la valeur de la firme (Bearle et Means, 1932). Les actionnaires, propriétaires de l'entreprise, en déléguant le pouvoir de décision aux dirigeants créent un conflit d'agence entre ces deux parties prenantes: les actionnaires ne peuvent être sûrs que les dirigeants vont prendre les décisions qui vont permettre de maximiser la création de valeur (Jensen et Meckling, 1976). Cela implique d'établir un certain contrôle des dirigeants.

L'exercice de ce contrôle est fonction de deux caractéristiques. La première caractéristique concerne la concentration du capital de l'entreprise. Afin de pouvoir participer à la surveillance et au contrôle de l'entreprise, l'actionnaire doit être suffisamment imposant pour internaliser le coût engendré par ces activités. Dès lors qu'un actionnaire dispose d'une part non négligeable du capital, il est capable et a intérêt à participer dans la gouvernance de l'entreprise afin de faire respecter ses attentes et celles des autres actionnaires par la même occasion (Shleifer et Vishny, 1986 ; Cronqvist et Fahlenbrach, 2009).

Le second déterminant du contrôle réside dans la nature de l'actionnaire. En effet, les actionnaires diffèrent dans leurs attentes et par conséquent dans leur manière d'interagir avec l'entreprise (Grossman et Hart, 1988). Par exemple un actionnaire souhaitant favoriser la création de valeur rapidement, et donc ayant des attentes à court terme, peut inciter le dirigeant à s'orienter vers des projets dont la génération de flux est proche dans le temps afin de faire augmenter la valeur de l'action à court terme. À l'inverse, un investisseur de long terme n'aura pas forcément intérêt à influencer les dirigeants de l'entreprise pour en faire ressortir des flux à

court terme. La typologie des actionnaires doit donc être prise en compte par celui qui cherche à comprendre son influence dans les décisions prises par l'entreprise.

Au-delà des caractéristiques des actionnaires, ces derniers disposent de plusieurs leviers pour influencer les décisions de l'entreprise. Le premier levier consiste à élire les membres du conseil d'administration. Le second concerne l'établissement d'un dialogue formel ou informel mais régulier avec les dirigeants de l'entreprise. Les actionnaires peuvent alors avoir accès à des informations privilégiées sur l'entreprise, sa stratégie, le comportement des dirigeants, etc. Ce dialogue s'étend naturellement aux droits qui leur sont accordés: le vote et les propositions d'actionnaire. Les actionnaires prennent part à certaines décisions prises par l'équipe dirigeante (politique de rémunération des dirigeants, vente d'actifs, etc.). Grâce aux propositions d'actionnaires, ces derniers ont la possibilité d'annoncer directement leurs souhaits, objectifs ou oppositions à l'entreprise et aux dirigeants.

Chaque actionnaire peut aussi exercer une influence en menaçant de vendre ses parts et en causant une chute du prix de l'action. Par exemple au cours de la fin de l'année 2006, le fonds Tracinda a menacé à plusieurs reprises de vendre ses actions dans General Motors (premier actionnaire du groupe) si le projet de fusion avec Renault-Nissan n'était pas accepté par l'entreprise. Le cours de bourse a largement réagi à la baisse suite à ces annonces. Finalement Tracinda a vendu 14 millions d'actions qu'il détenait à la suite du refus de l'entreprise d'entreprendre la fusion. Ces deux éléments font référence aux concepts de gouvernance de *Voice* et *Exit* mis en évidence par Edmans (2009).

La littérature a appliqué ces théories à l'étude de l'innovation. L'innovation, étant synonyme d'incertitude, implique l'entreprise dans une démarche de revenus à long terme, la structure actionnariale et les différents investisseurs la composant peuvent l'interpréter différemment. Plusieurs publications ont analysé l'effet de la concentration de l'actionnariat d'une part, et le type d'investisseurs d'autre part sur les dépenses en R&D ainsi que le succès des innovations.

Hill et Snell (1988) ainsi que Baysinger *et al.* (1991) montrent que la concentration de l'actionnariat et les dépenses de R&D sont positivement corrélées. Les auteurs décrivent deux mécanismes pouvant expliquer leurs résultats. Premièrement, les entreprises disposant d'activités d'innovation attirent les investisseurs en raison des rendements positifs que peuvent dégager de telles activités. Le risque inhérent à ces activités et la possibilité de rendements faibles ne réduisent pas l'intérêt des investisseurs car ils peuvent se diversifier ou vendre leur détention. Deuxièmement, Baysinger *et al.* (1991) suggèrent que ces investisseurs, en détenant

une part significative du capital font face à un problème de liquidité. Ainsi, ces investisseurs ont tout intérêt à s'impliquer dans l'entreprise afin d'orienter les stratégies de R&D vers des projets à forte création de valeur.

Hoskisson *et al.* (2002) démontrent que les fonds de pensions préfèrent les outils d'innovation interne (R&D) en raison de leur portefeuille d'investissement diversifié et à long terme. Au contraire, les fonds d'investissement professionnel qu'il définit comme les *mutual funds* et les banques d'investissement, favorisent les outils externe (M&A) en raison d'objectif de rentabilité à court terme. Cette contribution des fonds de pensions est due au fait qu'ils ne peuvent retirer leurs fonds facilement sans détruire de la valeur pour leur portefeuille. Ils sont donc dans l'obligation de créer des revenus à long terme.

Plus récemment, Aghion *et al.* (2013) démontrent aussi que les investisseurs institutionnels favorisent l'innovation. Selon les auteurs, la présence d'investisseurs institutionnels réduit le risque de congédier le dirigeant d'entreprise en cas de mauvaise performance. Cela incite donc le dirigeant à se tourner vers des activités plus risquées dont l'investissement en innovation.

Dans le courant de la littérature s'attachant à étudier la typologie des actionnaires, Bushee a publié plusieurs recherches mettant en évidence le rôle distinct des investisseurs sur la politique d'innovation. L'auteur démontre que les actionnaires dont le portefeuille est peu diversifié et dont le taux de rotation est important (appelé *transient investors*) favorisent la réduction des dépenses de R&D, suggérant un effet négatif pour l'innovation. À l'inverse, les actionnaires dont le portefeuille est peu diversifié mais dont la période de détention est à long terme (appelés *dedicated investors*) vont avoir tendance à favoriser les dépenses en R&D. Bushee (2001, 1998) montre alors que les attentes diffèrent selon l'actionnaire et peuvent impacter les politiques d'innovation mises en place au sein de l'entreprise.

En suivant le même raisonnement, Brav *et al.* (2018) montrent que les *hedge funds*, souvent à l'origine de stratégies de court terme, peuvent être à l'origine d'une amélioration du processus d'innovation. En effet, dans leur article, les auteurs prouvent que l'arrivée d'un *hedge funds* au sein d'une entreprise entraîne, dans un premier temps, une diminution des dépenses en R&D mais par la suite les brevets déposés jouissent d'un plus grand nombre de citations. Cela suggère que l'innovation est de meilleure qualité.

Finalement, la littérature est incapable de trancher sur les effets de la structure actionnariale sur l'innovation. La relation qui unit la structure actionnariale et la politique d'innovation est bien

fonction de différents éléments, dont la concentration ainsi que de la typologie des actionnaires présents au capital de l'entreprise.

Notre travail s'inscrit dans cette littérature en étudiant la relation entre la structure actionnariale et la mise en place d'une politique d'innovation ouverte (Chapitre 1). Ce chapitre permettra de tester empiriquement les prédictions de la littérature mais dans le cadre d'un nouveau champs d'étude, celui de l'innovation ouverte lorsque la majorité de la littérature étudie le résultat de l'innovation ou l'effet des dépenses en R&D.

3.2. Le rôle du conseil d'administration

Le conseil d'administration est l'organe de prise de décisions au sein de l'entreprise et ses membres sont élus par les actionnaires. Dès lors, en théorie, le conseil d'administration représente les intérêts de ces derniers et a pour objectif de maximiser de la valeur de la firme.

Néanmoins, les scandales financiers qui ont éclaté au début du XXI^{ème} siècle ont remis en question cette mission implicite du conseil d'administration. Les dirigeants de grandes entreprises telles qu'Enron, WorldCom ou encore Tyco ont mené des manipulations comptables entraînant des pertes pour les actionnaires. Ces scandales témoignent d'un placement des intérêts privés, ceux des dirigeants, avant les intérêts des actionnaires. Ces éléments ont donné lieu à une série de lois aux États-Unis (lois Sarbanes-Oxley mises en vigueur en 2002) dont l'objectif est d'augmenter le rôle de surveillance des conseils d'administration et l'indépendance des vérificateurs externes des comptes sociaux.

Le conseil d'administration d'une entreprise revêt alors un rôle dual: celui de surveillance des actions du dirigeant et celui de conseiller stratégique. Plus concrètement le conseil d'administration est responsable des décisions stratégiques et financières telles que les fusions-acquisitions ou bien des changements dans la structure capitalistique de l'entreprise ainsi que du recrutement et du renvoi des dirigeants de l'entreprise (Ferreira, 2011).

Le rôle de surveillance du conseil d'administration, ou encore défini par le terme *monitoring* dans la littérature anglo-saxonne renvoie à la capacité de contrôler les actions et décisions du directeur général de l'entreprise. Une première forme de contrôle réside dans la capacité du conseil d'administration à congédier ou menacer de congédier un dirigeant en raison de décisions impactant négativement la performance de l'entreprise (Jenter et Kanaan, 2015 ; Kaplan et Minton, 2012).

La notion de contrôle s'étend au concept d'indépendance du conseil d'administration. Un administrateur est indépendant dès lors qu'il n'a pas de conflit d'intérêt avec l'équipe dirigeante de l'entreprise: absence de liens familiaux et amicaux, absence de lien professionnel dans le cadre de l'entreprise (mission de conseil ou autres). En pratique, les membres indépendants des conseils d'administration, appelés par le terme *outsiders* dans la littérature, sont issus d'autres entreprises. Un conseil d'administration indépendant serait capable de questionner l'équipe dirigeante de l'entreprise lorsque cela est nécessaire afin d'éviter la priorisation des intérêts privés. La présence de membres indépendants permettrait alors de réduire les problèmes d'agence et d'améliorer la performance de l'entreprise.

Si l'apport de l'indépendance des membres du conseil d'administration est clair en terme de contrôle, les effets sur la performance de l'entreprise sont moins évidents. Bhagat et Black (2000) ainsi que Weisbach et Hermalin (1991) montrent que l'augmentation du nombre de membres indépendants présents au conseil d'administration n'implique pas une meilleure performance de l'entreprise. Néanmoins, il semblerait qu'une relation existe entre les changements de la structure du conseil d'administration et la performance de l'entreprise. Rosenstein et Wyatt (1990) montrent que le cours de l'action réagit positivement à l'arrivée d'un *outsider*. Hermalin et Weisbach (1998) identifient quant à eux que la probabilité que des *outsiders* intègrent le conseil d'administration augmente après une période de mauvaise performance de l'entreprise. Le marché interprète donc la présence d'*outsiders* positivement. Si l'indépendance du conseil d'administration n'assure pas une meilleure performance dans l'absolu, les changements de gouvernance tendent à améliorer la performance de la firme. Les *outsiders* semblent améliorer le contrôle des dirigeants et apporter des conseils utiles pour les périodes de refonte stratégique.

Ce dernier élément permet d'illustrer la fonction stratégique du conseil d'administration. Les membres du conseil apporteraient des ressources à l'entreprise au travers de leurs expériences, connaissances mais aussi leurs réseaux. Cette fonction est décrite dans la théorie de la dépendance des ressources de Pfeffer et Salancik (1978). Selon les auteurs, les entreprises sont dépendantes de facteurs externes qui ne sont pas sous leur contrôle. Ces dépendances génèrent des risques et de l'incertitude pour l'entreprise. Les administrateurs, en étant à l'interface de l'entreprise et son environnement, sont à même de réduire les incertitudes et les coûts de transactions auxquels font face les entreprises. Un conseil d'administration composé de différents profils et expériences se révélerait plus pertinent qu'un conseil composé de membres ayant des profils similaires. Haynes et Hillman (2010) démontrent que la diversité des

connaissances et profils composant le conseil d'administration favorise les changements de stratégie au sein des entreprises.

Les conseils prodigués sont en réalité complémentaires à la fonction de surveillance du conseil d'administration. Selon Adams et Ferreira (2007), un conseil d'administration dominé par la fonction de contrôle n'incite pas le dirigeant à partager sa connaissance de l'entreprise et ses projets: cette information pourrait être utilisée à son encontre en cas de mauvaise performance et le mener à sa démission. Cependant, dès lors que le conseil équilibre ses deux fonctions, le dirigeant a tout intérêt à partager l'information avec les autres membres et obtenir des conseils et avis qui pourront être déterminants dans la bonne gestion de l'entreprise.

Dans le cadre des politiques d'innovation, le contrôle ainsi que la capacité de recommandations des membres du conseil d'administration ont tout à fait leur place. Les résultats de l'innovation sont incertains, c'est donc un terrain propice au problème d'agence: un dirigeant dont l'aversion au risque est significative ne favorisera pas l'innovation, surtout si l'éventuelle faillite du projet d'innovation devait pousser les membres du conseil à le congédier. Par ailleurs l'apport de connaissances et expertises des membres du conseil d'administration permet d'accumuler des informations sur des projets d'innovation et réduire l'incertitude relative à l'innovation. Ainsi, le contrôle du dirigeant mais aussi la fonction de conseiller stratégique sont primordiaux pour favoriser la mise en place de politiques d'innovation.

La littérature semble conclure à une relation positive entre innovation et indépendance du conseil d'administration. Brunninge *et al.* (2007) prouvent que les *outsiders* ont un impact positif sur la stratégie du groupe et la politique d'innovation. Cela serait essentiellement dû au fait que de tels membres sont capables d'accumuler des connaissances et donnent des conseils plus avisés en terme de stratégie grâce à leur expérience dans un autre domaine.

Dans des travaux plus récents, Lu et Wang (2018) et Balsmeier *et al.* (2017) démontrent l'existence d'une relation entre le ratio d'indépendance du conseil d'administration et l'innovation au sein de l'entreprise. Les deux études démontrent que cette relation est causale. Néanmoins ils diffèrent dans l'interprétation de la relation. Selon Lu et Wang (2018), un conseil plus indépendant permet la mise en place de schéma de compensation favorisant une prise de risque plus importante de la part du dirigeant et donc plus d'innovation. Cependant, selon Balsmeier *et al.* (2017), un conseil d'administration plus indépendant incite l'entreprise à entreprendre des activités d'innovation moins radicales et moins exploratoires en favorisant les dépenses en R&D et le développement de brevets dans un domaine proche de celui de

l'entreprise. D'après les auteurs, la hausse du ratio d'indépendance augmente le contrôle des dirigeants, incitant ces derniers à se tourner vers des activités moins risquées.

Bien que moins développée, la littérature s'est interrogée sur le lien entre innovation et les ressources des membres du conseil d'administration (expertise, réseaux, etc.). Les compétences du dirigeant de l'entreprise ont un impact direct sur les activités d'innovation des entreprises selon Custódio *et al.* (2017). Les entreprises dirigées par un dirigeant généraliste ont tendance à déposer plus de brevets, ces derniers étant aussi plus cités. Ce genre de dirigeant serait plus tolérant à la faillite et donc moins « effrayé » d'être congédié en cas de mauvaise performance car leurs compétences sont facilement transférables à d'autres contextes et entreprises.

Le réseau du dirigeant est aussi un déterminant à l'innovation. Selon Faleye *et al.* (2014), les dirigeants ayant un réseau développé sont plus à même de mettre en place des politiques d'innovation. En étant connectés à de nombreuses entreprises, les dirigeants entretiennent des opportunités d'emploi en cas d'échec d'un projet innovant. Ce réseau leur apporte une assurance d'être employé dans une autre entreprise en cas de mauvaise performance.

Par ailleurs, ce réseau traduit la capacité d'un administrateur à capter des informations à l'extérieur de l'entreprise. Plus un administrateur dispose d'un réseau important, plus il est à même d'accumuler des connaissances et des informations quant à divers projets d'innovation. Cela permet de réduire les asymétries d'information ainsi que l'incertitude relative à l'investissement en innovation (Coles *et al.*, 2012).

Le second chapitre de cette thèse se propose d'étudier la relation entre la composition du conseil d'administration et les politiques d'innovation des entreprises. Nous contribuons à la littérature existante en intégrant dans notre étude l'ensemble des caractéristiques ayant une certaine probabilité d'influencer l'innovation. D'après notre connaissance, la littérature n'a étudié ces éléments que de manière isolée en se concentrant sur le rôle d'un type de membre du conseil d'administration (*outsider* ou non) et une seule caractéristique à la fois (réseaux, expertise, etc.). L'étude menée dans ce chapitre utilise différentes dimensions du rôle de conseil stratégique tout en identifiant les deux types d'administrateurs. Cela permet de mettre en évidence si un type d'administrateur est plus à même de favoriser l'innovation au sein de l'entreprise ainsi que d'identifier par quel moyen.

3.3. Structure financière des entreprises et politique d'innovation

Une entreprise dispose de trois types de financement pour ses projets dont chacun comporte un coût différent: le financement interne, bancaire ou par émission de capital. Si la majorité des entreprises favorisent le financement via des fonds internes, ces dernières ont souvent recours à des financements externes pour diverses raisons et objectifs.

Modigliani et Miller sont les premiers chercheurs à avoir théorisé la structure financière des entreprises. Dans leur premier article publié en 1958, ils énoncent que la valeur de l'entreprise n'est pas fonction de la structure de financement. Cependant cette théorie repose sur l'hypothèse de perfection des marchés (supposant l'absence de potentielles asymétries d'information) et ne prend pas en compte la fiscalité ainsi que l'existence d'une dette risquée.

Dans leurs publications suivantes les deux auteurs prennent en compte une partie des critiques et estiment que la valeur de l'entreprise peut être fonction de sa structure de capital notamment grâce à la présence d'économie d'impôts en présence de dette financière. Le financement bancaire, en induisant une économie d'impôts permettrait de réduire la rentabilité exigée par les apporteurs de capital et augmenter la valeur de l'entreprise.

Depuis les papiers de Modigliani et Miller, différentes théories sur la structure de capital des entreprises ont vu le jour. Ces théories intègrent de nouveaux critères pour expliquer les déterminants de la structure capitalistique des entreprises. Ces critères intègrent les coûts de faillites (Warner, 1977), la présence d'asymétrie d'information (Myers et Majluf, 1984) ou bien les droits de contrôle accordés lors de financement externes (Hart, 1995). L'arbitrage entre les différents coûts et avantages des sources de financement guide le choix des entreprises.

Dans le cadre du financement de l'innovation, la structure de financement s'avère être importante dans la mesure où l'innovation génère d'importantes incertitudes, un biais dans les rendements et comporte de nombreuses asymétries d'information. Dès lors il est possible que certains acteurs soient plus à même de la financer que d'autres.

La littérature s'est intéressée au rôle des marchés de capitaux d'une part, et des banques, d'autre part dans le financement de l'innovation. L'effet d'un financement par le marché semble influencer positivement l'innovation des entreprises. Le financement par capital semble être largement utilisé par des entreprises innovantes (Acharya et Xu, 2017 ; Brown *et al.*, 2009). Les entreprises favoriseraient l'émission de capital à la contraction de dette pour financer leurs

projets de R&D dans la mesure où ces entreprises sont caractérisées par d'importantes asymétries d'information, de l'incertitude et l'absence d'actif à donner en garantie.

Néanmoins, divers articles étudient la relation entre la dette bancaire et l'innovation et trouvent des résultats contradictoires. D'une part, Hall et Lerner (2010) décrivent que les banques ne sont pas à même de financer l'innovation en raison de leur aversion au risque, des orientations à court terme et l'absence d'intérêt à augmenter la valeur de la firme.

D'un autre côté, plusieurs recherches académiques démontrent l'existence d'une influence de la dette bancaire sur l'innovation des entreprises. Nanda (2014) prouve que le choc négatif sur l'offre de crédit engendré par la crise de 1929 a négativement impacté l'innovation des entreprises. Cela implique que les entreprises utilisent bien de la dette bancaire pour financer leurs innovations. Par ailleurs, Mann (2018) démontre que les entreprises innovantes ont souvent recours à de la dette et utilisent leurs brevets comme garanties. Enfin Robb et Robinson (2014) démontrent que le recours à de la dette bancaire est courant pour les entreprises engagées dans des activités d'innovation, même sans avoir de garantie à donner.

Face à des résultats contradictoires sur le rôle de la dette dans le cadre du financement de l'innovation, cela incite à s'interroger sur la composition de la dette d'une entreprise. Notamment, la présence de créanciers de divers types peut modifier l'équilibre et les incitations des créanciers initiaux.

Au-delà de l'étude de la dichotomie entre financement par capital et dette, un champ de la littérature s'est intéressé à la composition de la dette des entreprises en étudiant notamment la distinction entre la dette émise sur les marchés financiers (dette obligataire) et celle contractée dans le cadre d'une relation bilatérale (dette bancaire).

D'après Rajan et Zingales (2003), l'émission d'obligations nécessite la production d'information publique. Cela permet à une multitude d'investisseurs d'analyser et de donner une opinion sur l'investissement. Dans le cas de l'innovation, les entreprises sont alors capables d'atteindre une foule d'investisseurs et d'augmenter la probabilité de convaincre l'un d'entre eux de financer le projet proposé. L'existence d'informations accessibles publiquement relative au projet d'innovation tend à diminuer l'asymétrie d'information entre l'entreprise et les investisseurs. Néanmoins, Holmstrom (1989) soutient que le financement par le marché induit des pressions à court terme sur les entreprises et leurs dirigeants. Cela les empêchant de financer des projets de long terme.

Atanassov (2015) donne une validation empirique de la théorie défendue par Rajan et Zingalès. Selon cet auteur, le financement par dette obligataire favoriserait l'innovation en entreprise en raison d'une plus grande flexibilité et tolérance à l'échec que les créanciers traditionnels. Plus généralement, il semblerait que l'innovation en entreprise soit impactée par les instruments de dette. Comme le montrent Chang *et al.* (2019), la présence de *Credit Default Swaps* (CDS) favoriserait l'émergence d'innovation de meilleure qualité.

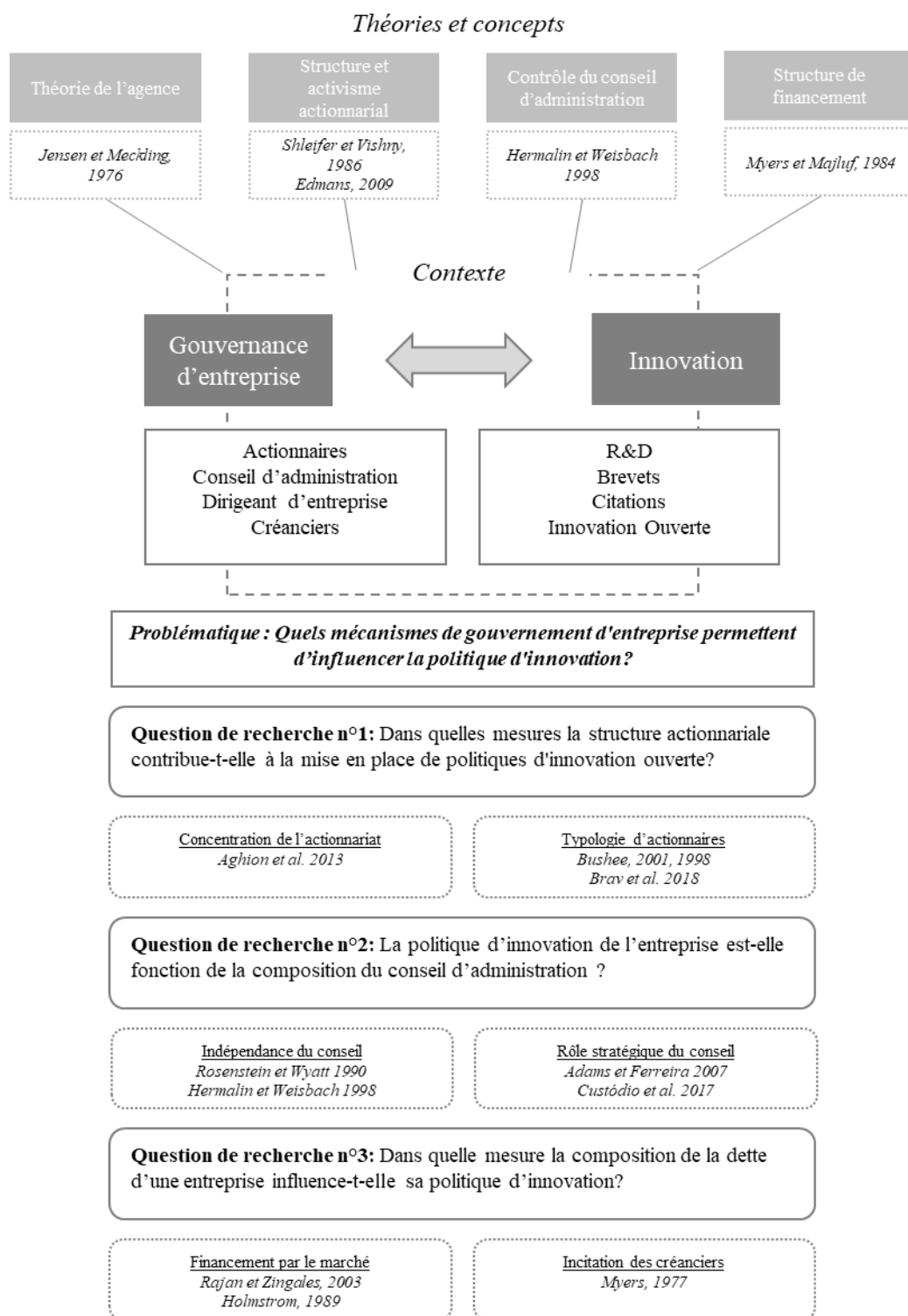
Nous positionnons notre travail doctoral au sein de la littérature en étudiant des situations particulières dans lesquelles les entreprises peuvent se trouver. Notamment, nous étudions la nature de la relation dans le cas où les actionnaires et créanciers auraient des intérêts divergent en matière de prise de risque. Nous nous appuyons sur les travaux de Myers (1977) statuant que les actionnaires ont une aversion au risque moins importante que les créanciers dans le cas où l'entreprise est proche du défaut. Cela permet de mettre en évidence la présence d'une relation non linéaire entre dette et innovation et d'en expliquer les raisons.

Ce manuscrit est organisé en trois chapitres. Le premier chapitre étudie le lien entre la structure actionnariale d'une entreprise et son choix en matière de politique d'innovation. Nous identifions si la présence de certains types d'actionnaires institutionnels favorise la mise en place de structures de capital-risque d'entreprise, considérées comme un outil d'une politique d'innovation ouverte.

Le second chapitre s'interroge sur le rôle du conseil d'administration dans le choix de la politique d'innovation. Plus précisément nous étudions comment s'articulent les rôles de conseiller stratégique et de contrôle dans le cadre de la politique d'innovation que nous évaluons selon son succès et les types d'innovation qu'elle promeut (radicales ou incrémentales).

Enfin, le troisième chapitre s'attache à décrire comment la structure de capital de l'entreprise influence le succès de sa politique d'innovation. Notamment, nous analysons la composition de la dette financière de l'entreprise et déterminons si la présence de dette obligataire et convertible permettent de favoriser l'émergence d'innovations lorsque l'entreprise fait face à des situations sous-optimales en matière d'investissement en innovation.

Graphique 0.3 : Schéma récapitulatif



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Chapitre 1. The influence of institutional investors on innovation processes: the case of Corporate Venture Capital

Abstract

The literature shows a positive influence of institutional investors on innovation output (i.e. patents and citations), thanks to their long term investment horizon and better monitoring. Instead, this paper asks what is their influence on the innovation process and focuses on one open innovation tool, namely Corporate Venture Capital (CVC) units. Such structures are an alternative to traditional models of innovation as they use internal resources to finance start-ups that are beyond the firm's boundaries. We find that the higher the percentage of shares held by institutional investors, the greater the propensity to open a CVC structure in a firm. This result is robust to various alternative sampling methods and the concentration of ownership. Moreover, we document that passive institutional investors drive this effect. Lastly, using the inclusion in the S&P 500 index as an instrument, we show that there is a causal relationship between the ownership by institutional investors and the opening of CVC units. Long term investment horizon, relieving risk of dismissing executives in case of failure as well as direct intervention and threat of exit are potential mechanisms that such investors could use to promote the opening of CVC structures.

1. Introduction

Long-term economic growth is driven by the technical progress and knowledge accumulated in economies (Romer, 1986; Solow, 1956). From the firm's perspective, in order to achieve long-term growth of profits, investments in innovative activities should be made. However, not all firms do so. Under-investment in innovation occurs notably because of divergences in expected long-term benefits and other issues.

The literature has identified several reasons that could hinder incentives for investing in innovation. For instance, managers can adopt myopic behavior and cut expenses in R&D in order to boost current earnings (Bushee, 1998; Porter, 1992). Risk-averse directors will avoid investing in innovation for fear of a bad outcome and getting dismissed (Holmstrom, 1989).

According to the agency theory, owners have a role in monitoring managers in order to align divergent interests of different stakeholders (Jensen and Meckling, 1976). Shareholders can monitor managers by either intervening or threatening to exit the corporation (selling their shares and reducing the share price), as stated by Edmans (2009).

Institutional investors (i.e. mutual funds, pension funds, banks, insurance, etc.) are particularly suited for monitoring managers into innovative activities. Such investors are sophisticated, are able to collect information on the invested firm, and are considered long-term investors. Moreover, the literature has proven their impact on innovative outcomes (Aghion *et al.*, 2013; Bushee, 2001, 1998).

This paper attempts to answer the question of how ownership structure can affect the innovation process of firms.

In order to answer the previous questions, we will study the relationship between ownership and innovation through the lens of Corporate Venture Capital (CVC). CVC funds allow a firm to take minority stakes in small companies in order to develop partnership and foster innovation (Gompers and Lerner, 2000). It is a particular way to innovate, as it develops ideas that are outside the boundaries of the firm with internal resources. Consequently, it is opposed to R&D, which only focuses on the use of internal resources, and M&A, which acquires innovative firms. The study of CVC allows us to focus on the implementation of the innovation strategy rather than the output and the result of it (e.g. study of the number of patents and citations). It enables us to look at a particular process of innovation. This way of financing innovation has been the subject of little attention in the literature. However, several papers have shown the positive

influence of CVC funds on innovation output (Dushnitsky and Lenox, 2005a; Gompers and Lerner, 2000; Ma, 2018).

Our results are based on a logit model with a dummy variable describing the presence of a CVC unit in the firm as the dependent variable. We model the outcome using a set of control variables and our main independent variable: the stake of capital held by institutional investors. We find that greater institutional ownership increases the likelihood of opening a CVC structure. This finding holds when we use concentration measures: ownership of the top 10 and top 5 largest shareholders are associated with a positive and significant coefficient.

When we split the institutional investors according to Bushee's classification we find that passive investors (quasi-indexers in Bushee's methodology) are associated with a positive effect on CVC openings. Dedicated investors are also promoting CVC structures, but only in sectors where many firms have a CVC unit. On the contrary, when companies are part of a sector in which few companies have a CVC unit, dedicated investors are negatively associated with the opening of a CVC structure. This may suggest that investors foster CVC units only when it is really needed. A negative and significant effect of transient investors is found only in the sample of firms in sectors with a few CVC structures (Bushee, 2001, 1998).

Lastly, following the methodology of Aghion *et al.* (2013), we use an instrumental variable and find a causal effect of institutional investors on CVC unit opening. We use the inclusion of the firm in the S&P 500 index as an instrument⁵ and show that the effect of institutional investors on CVC is still positive and significant.

We suggest several interpretations for the findings. First, institutional investors are not short-term oriented. Due to their large holding they face a liquidity issue and are unable to sell their stake. Consequently, they have more incentive to develop long-term projects. Such investors alleviate short-term pressure on managers and reduce manager myopia. Managers are able to focus on long-term value creation projects.

Second, the impact can be driven by the monitoring role of institutional investors. Such investors can use their sizable ownership stakes to wield influence and orientate strategic decisions towards innovative activities.

⁵ A dummy variable equal to one if the firm i is part of the index at year t .

This paper contributes to the literature in several ways. The main contribution is to put the CVC structure at the heart of the agency theory and the monitoring role of shareholders. To our knowledge, no research has been done on the link between CVC units and ownership of a corporation, as most studies are considering R&D expenses or innovation output (*i.e.* patents and citations). Second, we use a broader sample than most studies on R&D and ownership. These papers often focus on the period before the early 2000s. Our paper uses a sample from 1995 to 2015 and covers several economic and innovation cycles.

The paper is organized as follows: section 2 describes the literature on CVC structure and the monitoring role of shareholders; section 3 presents the data and the empirical methodology of the paper; section 4 details the results obtained, and section 5 concludes our findings.

2. Literature review and hypothesis development

This section describes the literature on CVC and its advantages for the firm, as well as the monitoring role of shareholders in order to develop long-term value creation projects and innovation. We also develop several testable hypotheses in this section.

2.1. The rationale of CVC structures

Intensive research has been conducted to identify the motivations and goals that corporations seek when creating a CVC unit. The role of CVC units is to combine the acquisition of knowledge and technologies, have potential access to a market or a technology, and have a financial return (Benson and Ziedonis, 2010; Dushnitsky and Lenox, 2005b). Moreover, Benson and Ziedonis (2009) and Higgins and Rodriguez (2006) argue that a prominent motive for CVC is the identification of entrepreneurial firm acquisition opportunities. They argue that a CVC program can act as information collection on the start-up mechanism in order to diminish the information asymmetry between the investor and the investee. Therefore, CVC plays the role of collecting information, promoting innovation with external stakeholders of the firm, and coordinates the flow of knowledge and resources between the corporation and the start-up.

Accordingly, CVC units are often part of the “open innovation” strategy of a corporation, which can be defined as the firm’s attempts to open up their internal innovation processes to external ideas (Chesbrough *et al.*, 2006). Open and closed innovation differs by the source of innovation.

In a closed innovation framework, products are developed by companies themselves. From the generation of ideas to the development and marketing, the innovation process takes place exclusively within the company. However, in an open innovation framework, the innovation process uses resources that are beyond the company boundaries. Innovation therefore arises through the interaction of internal and external ideas. The company's own employees, but also customers, suppliers, universities, competitors, or companies of other industries can be integrated in the process. For that reason, CVC differs from traditional ways of innovating, such as R&D and M&A.

CVC activity is driven by both firm-related factors and industry. The amount of cash flows, patent stock, R&D expenses, and firm size are positively related to the level of corporate venture capital investments (Dushnitsky and Lenox, 2005b). Moreover, firms' technology and marketing resources induce a higher level of CVC activity and a greater number of partnerships (Basu *et al.*, 2011). Lastly, Ma (2018) shows that CVC activity is driven by the innovation cycle of the firm: When facing a decline in its innovation output the firm will put in place a CVC unit in order to generate patents. The firm will close the CVC unit when its innovation output is reasonably high.

At the industry level, weak intellectual property regimes and technological sectors are positively related to the level of corporate venture capital investments (Dushnitsky and Lenox, 2005b). Institutions and regulations that affect innovation-oriented entrepreneurship also play a role in driving companies to adopt CVC: companies in countries with a developed market for early-stage investments are more likely to engage in CVC, while costly personal bankruptcy regulations are associated with lower propensity to use CVC practices (Da Gbadji *et al.*, 2011). Moreover, the level of competition among firms increases the probability to open a CVC, as stated by Basu *et al.* (2011).

Complementarity between the corporation and the invested company is also a determinant to CVC activity (Gompers and Lerner, 2000). Hellmann and Puri (2008) find evidence of such behavior for banks. When investing through their VC arm in young ventures, banks will seek complementarities with their business i.e. the lending activity. Indeed, banks will invest in high-debt industries. They also show that having prior venturing ties significantly increases the chance of the bank to become the company's lender. Last, Hellmann (2002) shows that a strategic partner will provide optimal funding when the start-up is complementary to the corporate investor.

Several papers have studied the outcome produced by CVC programs from the perspective of the corporations. CVC units improve the quality of patent developed by the corporation: Dushnitsky and Lenox (2005a) find a positive impact of CVC on the innovation capability of the firm, measured as the citation-weight patents. Wadhwa *et al.* (2016) find an inverted U-shaped relationship between the corporate investors' portfolio diversification and firm innovation. Finally, Dushnitsky and Lenox (2006) show that CVC activity increases the value of the invested firm and this effect increases when corporate partners invest with a strategic vision rather than a purely financial one.

By studying CVC structures we are able to look at the choice of innovation strategy made by the firms rather than its output (i.e. in quantity and in quality). Therefore, this paper does not study innovation per se but one of the processes to reach it.

2.2. The influence of ownership on corporate innovation

In the agency theory framework investors play a role in monitoring managers in order to maximize firm's value. As a consequence investors will have an interest in intervening in the management of the firm when managers take decision that do not fulfill the prime objective of shareholders.

Dispersed ownership magnifies the problem by giving rise to conflicts of interest between the various corporate claimholders and by creating a collective action problem among investors. No investors will be able to bear the cost of a collective action or associated with the monitoring of the managers (Shleifer and Vishny, 1986). In this paper we focus on the role of institutional investors who are often considered as having large stakes in companies and therefore being able to monitor managers.

Hirschman (1970) was the first to identify the main mechanism of action available to institutional investors when they disagree with the management of their portfolio firms. Investors can either engage with the management in order to try to change the strategy of the firms (the author uses the term "voice" to define this direct intervention), or they can sell their shares and leave the firm (this is the "exit" mechanism or "voting with their feet"). There is a vast amount of literature that demonstrates the positive effect of governance and discipline management through voice or exit.

There are several mechanisms by which shareholders can intervene (Becht *et al.*, 2002). First, shareholders are responsible for choosing and electing board members. This has a direct effect on the strategy of the firm, as shareholders will try to propose candidates that will succeed in maximizing the value of their investment.

Second, shareholders are able to raise a proxy fight in order to reach an important decision or remove an inefficient manager. With this action, investors are able to express their disagreement with the management of the firm.

Third, investors design incentive contracts that align the interest of the managerial teams with theirs. Such contracts typically index a part of the executives' remuneration to the performance of the company. The objective is to grant the executives with additional income if the decision taken improves the performance of the firm.

Last, they can threaten the company with a class action lawsuit. With this type of action, shareholders are actually suing the corporation for damages they may have suffered.

Moreover, investors are able to create events in order to discuss with the management informally, without any official actions taken. This includes, calls, meetings, etc. in which an investor is able to talk directly with the management of their portfolio firm.

In the innovation context, such intervention and monitoring is of first importance. Innovation is characterized by high uncertainty and risk, as well as specific knowledge and investments. Consequently, investors face higher agency issues that could be reduced by better monitoring. Academic papers that have looked at the role of institutional investors on innovation seem to agree on their positive influence.

There is a positive correlation between a firm's ownership concentration and R&D expenses (Baysinger *et al.*, 1991; Hill and Snell, 1988). According to the authors, investors are attracted by the potential value of such firms. Moreover, the illiquidity of their stake incentivizes them to focus on long-term value-creation projects such as R&D.

More recently, Aghion *et al.* (2013) find that institutional investors have a positive impact on both R&D expenses and R&D productivity. This effect is due to a better monitoring of the managers by investors: With increased institutional ownership, CEOs are less likely to be fired in the face of profit downturns. Previously, Bushee (1998) had found that higher institutional ownership would lead to less myopic pressure on managers and higher R&D spending.

Other types of investors can also positively influence the innovation policy of a firm. Brav *et al.* (2018) show in their paper that the arrival of an activist hedge fund will improve the efficiency of R&D spending: fewer R&D expenses for a better, higher quality innovation. One of the channels of such impact is the change in corporate governance after the arrival of the hedge fund: CEOs of targeted firms have longer tenure, which improves the risk-taking activity. Contrary to common belief, hedge fund activists are not simply short-term oriented but can improve the innovation output of a firm.

Chemmanur *et al.* (2016) investigate the impact of institutional cross-holding on the formation of strategic alliance between firms. They find that companies having common institutional blockholder have a higher propensity to enter a strategic alliance. Their results show a positive and causal relationship between strategic alliance and innovation.

The literature cited previously allow us to formulate the first hypothesis of our paper:

H1: Institutional investors will positively influence the likelihood of opening a CVC structure.

Even if institutional investors are often considered as a whole, they can be split into different categories according to their objectives and behavior. In his papers, Bushee analyzes the influence of each type of institutional investor classified according to their portfolio turnover and diversification. Investors are either dedicated investors (low turnover and low diversification), transient (high turnover and high diversification), or quasi-indexers (low turnover and high diversification).

Bushee (1998) shows that a firm with dominant transient ownership will decrease its R&D expenses. Such investors put short-term pressure on managers as they react strongly to quarterly earnings, preventing the firm from investing in R&D.

Aghion *et al.* (2013) find that, taken together, dedicated and transient investors increase the innovation output measured by the citation of patents. However, they do not find evidence of the impact of quasi-indexer investors. Their finding for transient investors is contradictory with Bushee's finding. They argue that institutional investors need to have a significant voice (such as dedicated) or a strong exit option (such as transient) in order to have an impact.

In a similar fashion, but with a different analysis, Hoskisson *et al.* (2002) show evidence that the type of investors affects differently innovation activities of the firm. He finds that pension funds would promote internal rather than external innovations. Thanks to their broadly

diversified portfolios and long-term ownership, such investors do not feel pressure for immediate returns. Therefore, this holding strategy encourages managers to undertake focused and opportunistic projects, such as R&D. On the contrary, professional investment fund managers (defined as mutual funds, banks, and investment banks) would rather enhance external innovation by acquiring innovative companies as they prefer immediate returns and treat investment in R&D as an expense and not an investment.

According to the literature, we formulate our second testable hypothesis:

H2 a: The higher the percentage of ownership by dedicated investors, the more it will increase the likelihood of opening a CVC structure.

H2 b: The higher the percentage of ownership by transient investors, the more it will decrease the likelihood of opening a CVC structure.

Quasi-indexers cannot govern through exit as their portfolio is based on indexing strategy. Since they hold a diversified portfolio they have few incentives to govern through voice. However, they are often the largest investors in companies, which enables them to govern by voting.

Appel *et al.* (2016) find that increased passive ownership leads to enhanced board independence and the removal of takeover defenses. They also find evidence that longer-term ownership via passive mutual funds is associated with significant improvements in firms' returns on assets (ROA) and Tobin's Q. Authors, therefore, suggest that an increase in passive investors would lead to greater levels of good corporate governance.

By way of contrast, Schmidt and Fahlenbrach (2017) find that exogenous change in passive ownership leads to increased power of CEOs and less appointments of independent boards. They show that shareholders react more negatively to the accumulation of titles and the appointment of new directors in firms with more passive owners. Finally, they also find that firms undertake more value-decreasing M&A deals after exogenous increases in passive ownership. The authors argue that the presence of passive investors at the firm is a good way to promote inexpensive corporate governance tools, such as decisions and monitoring that only imply to vote at shareholders meetings. However, greater passive ownership could negatively affect corporate governance when the firm engages in activities that necessitate high cost monitoring (e.g. M&A, choice of board members or accumulation of titles by managers).

Considering the contrasted view about passive investors and quasi-indexers, a formal hypothesis about the impact of such investors will not be proposed in this paper, though it will be analyzed.

3. Data and methodology

This section presents the databases used to create our samples and define the variables used in the paper. We dedicate a subsection to Corporate Venture Capital structures in order to describe trends of such innovative processes. We also present our empirical methodology and comment descriptive statistics.

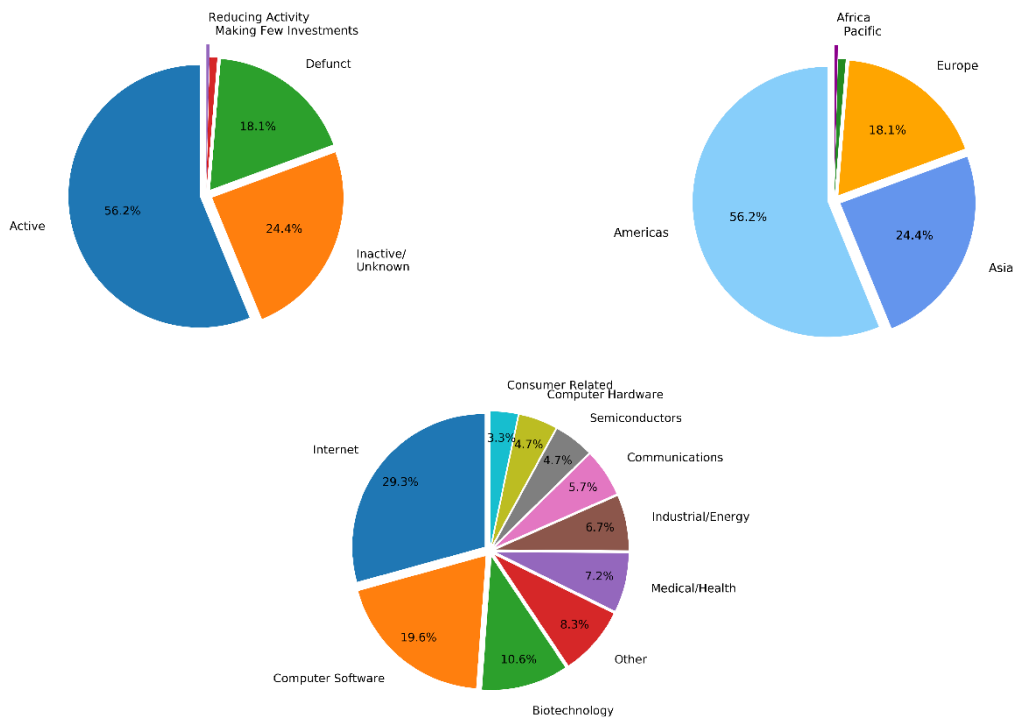
3.1. CVC identification

CVC firm identification is made through the Thomson's VentureXpert database. This database records the companies that have or have had a CVC branch between today and 1968. This provided us with 2,517 companies, mostly (but not exclusively) based in the USA. This data contains information on the foundation date of the CVC branch, the parent company, the national headquarters of the firm, and other variables relative to the investments.

The analysis presented in this section contains some basic information about companies that have a CVC branch. As one can see in Figure 1.1, most of the firms present in the VentureXpert database have an active CVC branch as of December 31, 2017. Only 18% of the firms have shut down their CVC activity between 1968 and 2017. In addition, CVC activity is mostly based in Northern America (predominantly based in the USA) and in technology-based sectors (internet, software, hardware, and biotechnology).

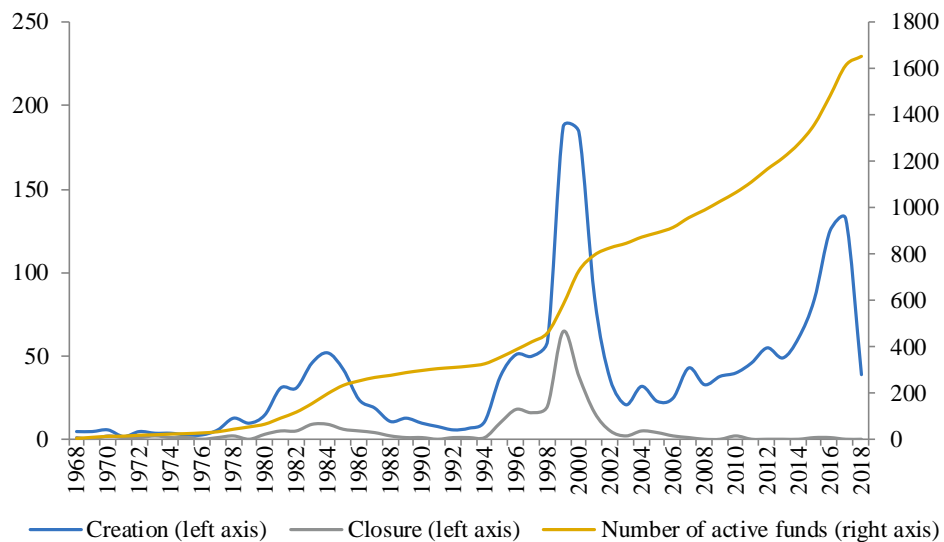
We are also able to compute in a time series the number of firm openings and closings, their CVC units, as well as the total number of firms having an active CVC unit. The Figure 1.2 illustrates the trends for all the companies available on VentureXpert.

Figure 1.1: Status, world location and sector of activity of CVC firms at the 31/12/2017



Source: VentureXpert

Figure 1.2: Dynamics of CVC structures



Source: VentureXpert

Based on the Figure 1.2, one can notice that CVC activity has been growing since 1968. One can also observe that several waves occurred since its beginning, as noted, with peaks in openings during the 1980s, 1990s, and the latter years.

The first wave one can see on the graph happened in the 1980s and was driven by the reduction of capital gain taxes and the ease of regulation of pension funds. CVC was seen as a diversification tool for corporations. However, CVC activity collapsed with the stock market crash of 1987 in the USA.

Thanks to the advent of the Internet in the mid-1990s, another wave of CVC emerged. A strong stock market and high returns led 400 corporations to create their CVC structure. Moreover, for the first time, companies were seeking disruptive technologies. It collapsed again when the dot-com bubble burst in the 2000s. However, if we could say that CVC has a cyclical activity, the recent wave seems to be more than just a fashionable trend: The number of CVC structures has been steadily growing over the years.

This dataset enables us to identify which companies have a CVC structure. To do so, we create a dummy variable equal to one if the company has a CVC unit at year t and zero otherwise. For the following sections, we will restrict our analysis to USA and Canada based companies.

3.2. Ownership data

Ownership data was collected through the Thomson Reuters database, which gathers the 13f SEC filings of every institutional investor that has more than \$100M of assets under management. The 13f SEC filing gives information on the stake held by an institutional investor in a public company: the number of shares held by the investor and total number of shares of the invested firm. Thus, this database is a panel in which each row describes the number of shares held by one investor in a company at a certain date. We downloaded data for the period between 1995 and 2015, providing us with several millions of observations.

Since the field of study is at the firm level, the previous database needs to be transformed in a panel based on the invested firm and provide information on its ownership. To do so, we sum up the shares held by each investor in one firm for each year and then divide it by the outstanding number of shares of the company in the same year. Such computation gives us the stake held by institutional investors in each company in the Thomson Reuters database for each year between 1995 and 2015.

Different types of investors is introduced according to Bushee's classification. In his papers, Bushee classifies institutional investors based on the turnover and the diversification of their portfolio. Investors are divided into three different groups:

- Dedicated investors that have low diversification and low turnover of the portfolio;
- Transient investors that have high diversification and high turnover;
- Quasi-indexer investors that have high diversification but low turnover.

We match the ownership database with the Bushee database in order to get the correct classification of investors. Such data allows us to compute the ownership variables according to the type of investor. We consider passive investors as quasi-indexer investors as they do not actively manage their portfolio but compose their portfolio based on an index. Dedicated and transient investors are both considered as active investors. However, they differ in their holding period. Transient investors are actively managing their portfolio but seek short-term returns as they are characterized by a high turnover. In contrast, we assume dedicated investors to be more long-term oriented.

Bushee's classification categorizes the managing firms rather than the fund itself. For instance, although Blackrock has many funds with different strategies and objectives, we classify the whole entity and not each fund. This is one of the limits in the paper as we do not take into account the potential differences in the trading strategy that exist between funds of the same investing firm.

The classification of investors made by Bushee is done in two phases. The first step proceeds at a factor analysis of variables that describe past investing activity of the institution. Bushee based its factor analysis on several proxies for portfolio concentration⁶ and turnover⁷. The author uses the principal component analysis and identifies two common factors among the variables given: the size of stock held in a portfolio firm and the degree of portfolio turnover.

After this, the author performs the k-mean clustering method in order to identify groups of investors. Bushee only identifies three groups of institutional investors, as described above. The main objective, according to Bushee, "was to find cluster solutions without disproportionate

⁶ Namely the concentration of the portfolio, the average percentage of stock held, the percentage held in large block and the Herfindahl measure of concentration.

⁷ The author uses the following variables: the portfolio turnover (change in the institution's ownership position over a quarter, scaled by the change in total equity of the institution) and the stability of holdings (percent of stock held for two years).

numbers of observations in some clusters [...] that closely match the theoretical reasons for splitting institutions into groups”.

One could wonder if a fourth group of investors could be identified, with a low diversification and a high portfolio turnover, such as hedge funds. However, the author do not mention it. We suppose that such type of investor is not sufficiently represented over institutions filling the 13f file, therefore, it is not possible to detail a particular group. It could also be possible that hedge fund investing strategies are very different from a fund to another, therefore being impossible to classify them properly.

3.3. Controls

In order to build a comprehensive dataset we incorporate basic accounting data relative to the firms in the sample. We used the annual filling of the Compustat database to download the following variables for the period 1995-2015: total asset, net income, R&D expenses, total cash, long term debt, shareholder equity, and market capitalization of the firm.

This data allows us to compute the following variables:

- Leverage ratio computed as the ratio between long term debt and shareholder equity;
- Return on Asset, computed as the ratio between net income and total assets;
- Market to Book, defined as the ratio between market value of the firm and the book value of equity (shareholder equity).

We also compute the Herfindahl index based on the total sales industry with two-digit SIC codes.

3.4. Empirical methodology and descriptive statistics

We merge our different datasets using the tickers. This results in a data frame describing the ownership of companies that have been matched (and therefore have a CVC unit) and those that have not (and therefore do not have a CVC unit). By including the firms without a CVC structure, we alleviate the risk of a selection bias in our sample. Firms are included in the samples irrespective of the presence of a CVC structure. The dataset is comprised of 31,962 observations. There are 4,421 different firms in the sample, of which 91 have a CVC fund.

The Table 1.1 describes common statistics for both subsamples of CVC and Non-CVC firms. All variables have been winsorized at the 1st and the 99th percentiles in order to remove the influence of outliers.

Table 1.1: Descriptive statistics

	Obs.	Mean	ST. Dev.	Skewness	Kurtosis	Min	Median	Max
Panel A: CVC firms								
Instit. Investors (%)	1,434	64.0	19.8	(1.0)	0.9	0.0	38.9	100.0
Dedicated Inv. (%)	1,434	2.4	3.9	2.8	10.1	-	0.0	93.1
Quasi-indexer Inv. (%)	1,434	46.3	16.0	(0.7)	0.5	-	24.8	96.0
Transient Inv. (%)	1,434	15.3	8.7	0.8	0.7	-	8.2	76.1
Firm size (log of total assets)	1,434	8.5	2.1	(0.4)	0.4	(1.7)	5.1	13.6
ROA (%)	1,434	0.0	0.1	(3.3)	17.3	(1.1)	0.0	0.2
MtoB (%)	1,434	4.2	3.8	2.0	6.8	(10.5)	2.1	27.5
HHI	1,434	0.0	0.0	4.0	20.9	0.0	0.0	1.0
Leverage (%)	1,434	0.5	1.6	(1.5)	178.6	(103.6)	0.1	631.0
log(1+Cash)	1,434	6.1	2.0	(0.4)	0.1	-	2.9	11.4
log(1+R&D expenses)	1,434	5.2	2.4	(0.7)	(0.2)	-	1.8	9.4
Panel B: Non CVC firms								
Instit. Investors (%)	30,528	39.8	29.1	0.2	(1.2)	0.0	38.9	100.0
Dedicated Inv. (%)	30,528	2.3	5.8	5.2	42.6	-	0.0	93.1
Quasi-indexer Inv. (%)	30,528	26.9	21.4	0.5	(0.9)	-	24.8	96.0
Transient Inv. (%)	30,528	10.5	10.6	1.2	1.4	-	8.2	76.1
Firm size (log of total assets)	30,528	5.2	1.9	0.4	(0.0)	(1.7)	5.1	13.6
ROA (%)	30,528	(0.1)	0.2	(2.2)	5.0	(1.1)	0.0	0.2
MtoB (%)	30,528	3.0	3.4	2.6	11.6	(10.5)	2.1	27.5
HHI	30,528	0.1	0.1	4.7	33.1	0.0	0.0	1.0
Leverage (%)	30,528	0.5	4.8	81.0	9,854.6	(103.6)	0.1	631.0
log(1+Cash)	30,528	2.9	1.8	0.5	(0.1)	-	2.9	11.4
log(1+R&D expenses)	30,528	1.9	1.7	0.7	0.2	-	1.8	9.4

The dataset consists of 1,434 observations relative to companies having a CVC unit and 30,528 that do not. The average of institutional ownership is 64% for the CVC firms and 40% for the firms without CVC units. In both samples, institutional investors are major stakeholders. Firms in our sample are large, and we can observe an important difference between CVC and non-CVC firms. Average firm size reaches \$4,914m for CVC firms and \$244.6m for non-CVC firms (respectively 8.5 and 5.2 in the table above which is computed as the log of total assets). Above all, we can observe that the two subsamples have very different values for the variables. Such descriptive statistics tell us that the CVC sample is composed of bigger, more established companies that are spending more in R&D than the non-CVC sample.

Correlation matrices are available in the appendix. Variables are all positively correlated with the exception of Market to Book and Return on Asset. All coefficients are statistically significant.

For regression purposes, we transform the variables of total asset, total cash and R&D expenses into a logarithm. The table below describes the variables used and their source, as well as the expected impact on the formation of CVC units.

Table 1.2: Definition of the variables

Var.	Definition	Source	Expected sign
CVC event	Dummy variable equal to one if the firm i has a CVC unit at year t	VentureXpert	
Instit. Investors (%)	Ratio between the number of shares held by institutional investors and the outstanding number of shares of a firm	SEC, Thomson	+
Dedicated Inv. (%)	Ownership held by dedicated investors	SEC, Bushee	+
Quasi-indexer Inv. (%)	Ownership held by quasi-indexer investors	SEC, Bushee	+ / -
Transient Inv. (%)	Ownership held by transient investors	SEC, Bushee	-
Firm size	Log of total asset of the firm (m\$)	Compustat	+
ROA (%)	Ration between the net income and the total asset of a firm	Compustat	+
MtoB (%)	Ratio between the market value and the book value of equity	Compustat	+
HHI	Herfindahl-Hirschman index based on 2 digit SIC code	Compustat	+
Leverage (%)	Ratio between the total debt of a firm and book value of equity	Compustat	-
Log(1+Cash)	Log of 1 plus the annual amount of cash held by the firm (m\$)	Compustat	+
log(1+R&D expenses)	Log of 1 plus the total annual expenses in Research and Development (m\$)	Compustat	+

To assess how institutional investors affect corporate innovation we estimate various forms of the following logit model:

$$CVC\ event_{i,t} = \alpha + \beta * Institutional\ ownership_{i,t} + \delta * Controls_{i,t} + \varepsilon_{i,t} + \mu_t + \mu_s \quad (1.1)$$

where i indexes the firm and t the year. Controls used in the model are identified through the literature and consist of firm size, level of competition (HHI), return on assets, market-to-book ratio, leverage ratio, amount of cash and R&D expenses. We run fixed-effects regressions with year and industry fixed effects (respectively μ_t and μ_s). Sectors are classified according to the SIC methodology, and we use two digit SIC codes for our fixed effects.

Since the number of firms having a CVC is small in relation to the full sample (CVC observations are approximately 5% of the total sample), we use the appropriate models to take into account this skewed ratio. We follow the methodology of King and Zeng (2001) for rare-event regression in logistic regression. Their methodology alleviates the issue of biased maximum likelihood estimation in small samples.

4. Main findings

4.1. The influence of institutional investors in the opening of CVC structures

Table 1.3 computes the baseline results of the paper. The first column describes the relation between CVC opening and institutional ownership alone. It shows a positive and significant coefficient for the level of institutional ownership. Therefore, the higher the institutional investors hold equity, the higher the likelihood of opening a CVC structure. As we are assessing the ability of investors to foster or not CVC activities and not the magnitude of the effect, the small value of the coefficient is not important to us. What is important is the sign and the significance of the coefficient.

The second and third columns introduce control variables. Institutional ownership is still positive and significant; however, the coefficient is much lower than in the first column (i.e. 0.010 vs. 0.032). Such results support the first hypothesis and confirm $H1$.

Consistent with the literature and our expectation, we find a positive and significant coefficient for firm size, HHI, ROA, market to book ratio, total cash, and R&D. The leverage ratio variable is negative and significant, but only when the R&D variable is not introduced.

The influence of institutional investors could be two sided as Aghion *et al.* (2013) stated in their paper. The first interpretation is based on the “quiet life” assumption of managers (Hart, 1983; Hick, 1935; Scharfstein, 1988) which supposes that when product market competition is not a real threat to the corporation, managers will avoid to take difficult and risky decisions and exert less effort. Consequently, institutional investors may motivate them to innovate by offering incentive contracts that offset the risk taken in innovative activities or closely monitoring them.

The alternative explanation remains in the career concern theory (Holmstrom, 1989). Because of reputation and fear of getting fired if innovative activities fail, managers will not take such risk and underinvest in innovation. Institutional investors can therefore, relieve such reputation concern and not dismiss the manager when the innovation activity does not perform well.

We also run the same regression by introducing clustering of standard errors at the industry level and find similar results. Such results are available in Panel A of Table 1.9 in the appendix.

Table 1.3: Institutional investors and CVC structures openings

	<i>CVC_event</i>		
	(1)	(2)	(3)
<i>Instit. investors</i>	0.032*** (0.001)	0.007*** (0.002)	0.010*** (0.002)
<i>Firm Size</i>		0.571*** (0.041)	0.300*** (0.043)
<i>ROA</i>		0.259 (0.329)	0.751** (0.324)
<i>MtoB</i>		0.030*** (0.011)	0.007 (0.012)
<i>HHI</i>		2.381 (1.895)	2.592 (1.841)
<i>Leverage</i>		-0.053*** (0.012)	-0.042*** (0.010)
<i>Log(1+Cash)</i>		0.317*** (0.040)	0.146*** (0.040)
<i>Log(1+R&D)</i>			0.512*** (0.036)
Year Fixed effect	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes
Observations	31,962	31,962	31,962
Log Likelihood	-4,179.840	-3,032.323	-2,924.001
Akaike Inf. Crit.	8,523.680	6,240.646	6,026.002

Note: This table presents the results of the logistic regression of the model presented in equation (1.1). Our dependent variable *CVC_event* is a dummy variable equal to one if the firm has a CVC structure in year t and zero otherwise. *Instit. Investors* is the percentage of shares held by institutional investors. *Firm size* is the logarithmic value of total assets of the firm. *ROA* is the ratio of net income over total assets. *MtoB* is the ratio between the market capitalization and book value of equity. *HHI* is the Herfindahl index computed with two-digit SIC codes. *Leverage* is the ratio between long term debt and total assets. *Log(1+Cash)* is the logarithmic value of cash available in the firm. *Log(1+R&D)* is the logarithmic value of Research and Development expenses available in the firm.

Significance levels: *p<0.1; **p<0.05; ***p<0.01

4.2. Investor concentration and removal of the 2000s period

In the next table, we test if the baseline results hold up against a variable taking into account the concentration of ownership. We ran the same regression than previously, but instead of using the total detention by all institutional investors, we introduced the detention by the top 10, top 5, and top 1 institutional shareholders. We also run the regression on a sample excluding the years 1999, 2000, and 2001, which saw numerous openings of CVC units. This last robustness test allows us to estimate the influence of investors outside of periods of investment bubbles that could create an upward bias in our estimations.

The first three columns of Table 1.4 run models using the concentration of ownership variables. Such variables compute the amount of equity controlled by the largest investors in the company. To compute these measures, we organize the stakes held by every investor according to the percentage of capital held in the firm. We compute variables describing the percentage of shares held by the largest investor (*Top 1 Instit. inv.*), the 5 largest investors (*Top 5 Instit. inv.*), and the 10 largest investors (*Top 10 Instit. inv.*). A high value for these variables indicates a greater concentration of ownership within the firm.

As we can see, the coefficients for the Top 10 and Top 5 investors are still positive and significant. This is consistent with the findings of Aghion *et al.* (2013). If the variable describing the ownership of the largest investor is not significant, it is, nevertheless, positive. Therefore, the effect of institutional investors on the opening of CVC structure is relatively stable.

Last, in column 4, where the model is estimated on a sample without years 1999 to 2001, we see a positive coefficient associated with the institutional investor variable. Our results hold up, even when we do not take into our sample periods of important CVC opening.

When running the same regressions but with clustered standard errors at the industry level we find almost similar results. We find positive and significant coefficients for the *Top 10 Investors* variable and the *Instit. Investors* when the tech bubble period of the early 2000s was removed. Therefore, the variable *Top 5 investors* is not significant with industry level clusters. Such results are available in Panel A of Table 1.9 in the appendix.

Table 1.4: Ownership concentration and 2000s exclusion

	<i>CVC_event</i>			
	Full Sample (1)	Full Sample (2)	Full Sample (3)	No 2000's (4)
<i>Instit. Investors</i>				0.010*** (0.002)
<i>Top 10 Instit. inv.</i>	0.009*** (0.003)			
<i>Top 5 Instit. inv.</i>		0.009*** (0.003)		
<i>Top 1 Instit. inv.</i>			0.005 (0.005)	
<i>Firm size</i>	0.331*** (0.043)	0.332*** (0.043)	0.330*** (0.042)	0.303*** (0.047)
<i>ROA</i>	0.941*** (0.330)	0.972*** (0.329)	0.986*** (0.327)	0.665* (0.361)
<i>MtoB</i>	0.011 (0.012)	0.010 (0.012)	0.008 (0.012)	0.016 (0.014)
<i>HHI</i>	2.445 (1.815)	2.392 (1.808)	2.338 (1.802)	2.254 (1.806)
<i>Leverage</i>	-0.043*** (0.010)	-0.043*** (0.010)	-0.041*** (0.010)	-0.079** (0.032)
<i>Log(I+Cash)</i>	0.156*** (0.040)	0.157*** (0.040)	0.159*** (0.040)	0.126*** (0.044)
<i>Log(I+R&D)</i>	0.501*** (0.036)	0.496*** (0.036)	0.490*** (0.036)	0.527*** (0.039)
Year Fixed effect	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes
Observations	31,962	31,962	31,962	26,655
Log Likelihood	-2,933.230	-2,935.796	-2,938.796	-2,508.054
Akaike Inf. Crit.	6,044.459	6,049.592	6,055.592	5,188.107

Note: This table presents the results of the logistic regression of the model presented in equation (1.1). Our dependent variable *CVC_event* is a dummy variable equal to one if the firm has a CVC structure in year t and zero otherwise. *Instit. Investors* is the percentage of share held by institutional investors. *Top 10 Instit. Inv.* is the percentage of capital held the 10 largest shareholders. *Top 5 Instit. Inv.* is the percentage of capital held the 5 largest shareholders. *Top 1 Instit. Inv.* is the percentage of capital held by the largest shareholders. *Firm size* is the logarithmic value of total assets of the firm. *ROA* is the ratio of net income over total assets. *MtoB* is the ratio between the market capitalization and book value of equity. *HHI* is the Herfindahl index computed with two-digit SIC codes. *Leverage* is the ratio between long term debt and total assets. *Log(I+Cash)* is the logarithmic value of cash available in the firm. *Log(I+R&D)* is the logarithmic value of Research and Development expenses available in the firm. Significance levels: *p<0.1; **p<0.05; ***p<0.01

4.3. Types of institutional investors: different horizons and objectives

Institutional investors can be very different from one another. According to their investment style, they have different aims and holding horizons. These differences may cause institutional investors to have different expectations about innovation, which is inherently a long-term investment. Thus, it is important to consider the heterogeneity among investors in our regressions.

To do so, we use the classification developed by Bushee (1998) and run our regression with the institutional investor variable split into three distinct variables: “dedicated” (institutions with a concentrated portfolio but not trading often); “quasi-indexers” (institutions with a diversified portfolio but not trading often); and “transient” (institutions with a diversified portfolio and trading often). Table 1.5 computes the results of the logit estimation with the classification of Bushee. In column 1, we ran the estimation on the full sample. We find a positive and significant coefficient only for quasi-indexer investors. The coefficient of dedicated investors is negative and non-significant. For transient investors we find a positive and non-significant coefficient. These results do not confirm our expectations or our hypothesis. Our hypotheses on dedicated (*H2 a*) and transient investors (*H2 b*) do not find support as the coefficients are not significant. However, according to our results, quasi-indexers seem to have a positive effect on CVC formation. These results are different from those found by Bushee (2001, 1998), who describes the negative influence of transient investors and positive influence of dedicated investors on R&D spending.

Furthermore, we ran the estimation on two different sub-samples: a sample restricted to sectors hosting many CVC units (column 2) and a sample with few or no CVC units (column 3). This allows us to gather information about different situations in which firms are and the influence of their shareholders. We could expect that an investor would not be keen on developing a CVC structure if it is not a standard in the sector. On the contrary, if a CVC structure is common in the industry because it showed its positive influence on corporate innovation, shareholders might be inclined to accept the opening of a CVC structure.

To identify our subsamples, we simply computed the sum of companies having a CVC structure over the period of 1995-2015 for each sector of our database. We considered the sectors being CVC-intensive when containing more than five CVC companies. Sectors considered CVC-intensive are the following (SIC are in parenthesis): Business Services (73), Chemicals (28), Electronics (36), Machinery and Computer equipment (35), Measure instruments (38). Taken

together, companies in these sectors account for more than 50% of the companies that have a CVC unit in the sample.

The results obtained from the CVC-intensive sectors are consistent with our expectations. We find positive and significant coefficients for dedicated investors. Moreover, we do also find a positive and significant coefficient for transient investors. When focusing on the CVC-extensive sectors we find a negative coefficient for dedicated and transient investors, although not significant for the latter.

These results are consistent with the findings of the literature describing a positive influence of dedicated investors on innovative activities due to their long term horizon (Aghion *et al.*, 2013; Bushee, 2001, 1998). Our result showing a positive impact of transient investors in the CVC intensive sample is rather surprising. However, the coefficient for transient investors is much lower (0.009 vs. 0.023 for dedicated investors), which suggests that they do not have a strong influence. Moreover, in other models the coefficient is not significant and negative. Nevertheless, our result could simply be explained by the fact that transient investors also agree on industry norms relative to the opening of a CVC structure.

In both subsamples, we find that quasi-indexers have a positive and significant coefficient. They are positively associated with the CVC opening. Therefore, we can argue that institutional investors and, more precisely, dedicated and quasi-indexer investors are in favor of opening a CVC structure in sectors where it may be needed. Transient investors, on the contrary, would be against the implementation of CVC units. These results confirm our hypotheses *H2 a* and *H2 b*.

Dedicated investors hold significant stakes but only in a few firms and for a long period. Such investors are well integrated into the company. Consequently, it is in their interest to create long-term value for the company. According to their holding characteristics, dedicated investors are prone to alleviating pressures for managers' myopic behavior by monitoring them and relying on sources of information other than earnings in order to assess management ability (Porter, 1992).

Such investors are able to take actions and intervene in the management of the firm in order to improve the value of their investment. Dedicated investors can talk to the management informally and gather knowledge about projects and the strategy of the firm. As they know the firm well they are typically the ones to raise proxy fights or shareholders proposals, making direct interventions when needed. Lastly, the threat of exit is also possible for this kind of

investors as they are not tied to an indexing investing strategy. Such elements enable dedicated investors to promote the opening of a CVC structure whenever it is considered positive for the corporation. This interpretation would explain why we find a positive coefficient in the CVC intensive sample and a negative coefficient in the CVC extensive sample.

While the impact of quasi-indexers is contrasted in the literature, our results suggest that they are positively associated with the implementation of CVC structures. Such a result supports the fact that index funds can be a good monitor of the firm in the case of innovation activities. Index funds can govern through voting thanks to their large and illiquid stakes in firms. According to Monks and Minow (2011), such stakes motivate quasi-indexers to monitor management in order to create long-term value for the firm. Our results confirm the thesis supported by Appel *et al.* (2016) stating that passive investors play a role in governance of the firm. Moreover, quasi-indexers could enhance the ability of more active investors to propose effective tools of monitoring as suggested by Appel *et al.* (2019). A greater presence of quasi-indexer could facilitate the decisions and propositions made by dedicated investors and promote the opening of CVC structures.

When estimating the same models but with standard errors clustered at the industry level we only find the *Quasi-indexers Inv.* variable to be positive and significant. Other types of investors are not significant in any of the samples. Such results reinforce our interpretation that the presence of quasi-indexers can be particularly positive for alternative innovation activities. The results are available in the Panel B of the Table 1.9 in the appendix.

Table 1.5: CVC structures opening and investor typology

	Baseline (1)	<i>CVC_event</i> High CVC (2)	Low CVC (3)
<i>Dedicated Inv.</i>	-0.003 (0.006)	0.023*** (0.009)	-0.031** (0.012)
<i>Quasi-indexer inv.</i>	0.013*** (0.002)	0.012*** (0.003)	0.011** (0.005)
<i>Transient Inv.</i>	0.005 (0.004)	0.009* (0.005)	-0.015 (0.010)
<i>Firm Size</i>	0.289*** (0.045)	0.077 (0.068)	0.479*** (0.085)
<i>ROA</i>	0.668** (0.322)	1.375*** (0.383)	1.290 (0.949)
<i>MtoB</i>	0.007 (0.012)	-0.025 (0.017)	0.076*** (0.027)
<i>HHI</i>	2.817 (1.822)	10.097 (7.201)	2.262 (2.578)
<i>Leverage</i>	-0.042*** (0.010)	-0.030 (0.052)	-0.056*** (0.011)
<i>Log(1+Cash)</i>	0.152*** (0.041)	-0.013 (0.050)	0.397*** (0.084)
<i>Log(1+R&D)</i>	0.508*** (0.036)	0.803*** (0.065)	0.429*** (0.059)
Year Fixed effect	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes
Observations	31,962	19,817	12,145
Log Likelihood	-2,920.056	-2,182.682	-652.323
Akaike Inf. Crit.	6,022.112	4,435.364	1,476.647

Note: This table presents the results of the logistic regression of the model presented in equation (1.1). Our dependent variable *CVC_event* is a dummy variable equal to one if the firm has a CVC structure in year t and zero otherwise. *Dedicated Inv.* is the percentage of capital held by dedicated investors. *Quasi-indexer Inv.* is the percentage of capital held by quasi-indexer investors. *Transient Inv.* is the percentage of capital held by transient investors. *Firm size* is the logarithmic value of total assets of the firm. *ROA* is the ratio of net income over total assets. *MtoB* is the ratio between the market capitalization and book value of equity. *HHI* is the Herfindahl index computed with two-digit SIC codes. *Leverage* is the ratio between long term debt and total assets. *Log(1+Cash)* is the logarithmic value of cash available in the firm. *Log(1+R&D)* is the logarithmic value of Research and Development expenses available in the firm. Significance levels: *p<0.1; **p<0.05; ***p<0.01

4.4. Alternative empirical specification as a solution to endogeneity

Identifying the impact of institutional investors on the opening of a CVC unit poses an empirical challenge. Cross-sectional correlations between ownership and innovation might not reflect a causal relation because ownership by institutional investors could be correlated with additional factors—such as firms’ access to capital, investment opportunities, innovation activities—that directly affect corporate outcomes. Failure to control for such factors could introduce an omitted variable bias that confounds inferences. We are facing an endogeneity problem: investors may select their target based on unobservable variables.

In order to resolve such endogeneity, we use the instrumental variable methodology. Following the methodology of Aghion *et al.* (2013), we use the inclusion of a firm in the S&P 500 as an instrument. We coded a dummy variable equal to one if the firm i is part of the index at year t and zero otherwise.

There are several reasons for which a firm of the S&P 500 is more likely to be owned by institutional investors. Indexed funds will be forced to invest in such companies, as it is their investment strategy. Whereas non-indexed funds often benchmark their investment against the S&P 500, there is an incentive to include in their portfolio firms that are in such index.

We run a two-stage regression to capture the effect of the instrument. We also apply the methodology on three different samples: the full sample, the sample restricted to CVC intensive sectors, and, last, the sample restricted to CVC extensive sectors. Table 1.6 summarizes the results obtained. The first column corresponds to the first stage of the instrumental variable estimation. We regress the S&P 500 dummy and all other controls on the Total institutional investor detention using OLS estimation. As before, we use year and sector (two digit SIC codes) fixed effects. We find a positive coefficient for the S&P 500 dummy, indicating that a firm included in the index will have more of its capital detained by institutional investors. This is consistent with our expectations.

The column 2 is the second stage of the estimation, where we regress the fitted value of institutional ownership and controls on the CVC dummy. The coefficient of institutional investors variable is positive and significant. We are able to argue that institutional ownership has a causal effect on the opening of CVC structure.

The same results hold when we apply the methodology on the restricted samples, except for the CVC intensive sector sample, where the coefficient of the total institutional ownership is positive but not significant.

We also show the p-value of the Hausman test applied to the instrument. All p-values are small, suggesting that institutional ownership is endogenous, except for the CVC intensive sample. For the case where the p-value of the test is small, it justifies the use of Instrumental variable methodology.

The fact that the coefficient of the institutional variable is positive in the case of the CVC extensive sample might be contrary to our previous results where we analyzed the impact of each type of investors. In Table 1.5, we found a negative coefficient for dedicated investors and a positive coefficient for quasi-indexers in the CVC-extensive subsample. Our interpretation is the following: The influence of institutional investors variables taken as a whole is driven by the presence of quasi-indexers. The positive influence of the latter could offset the negative influence of other types of investors and lead to a positive influence of the institutional investor. Moreover, quasi-indexers are often the largest investors in a corporation and could have the strongest influence in corporate governance rules.

Our result however must be taken with care. The inclusion of a firm in the S&P 500 is not completely random: in order to be included, a company must have been small in the past and large today. It is possible that the stock market anticipates the rise in innovation among such firms and value them better which eventually make them included in the index.

Moreover, when we run the same methodology with standard error clustered at the industry level, we find only one sample in which the *Instit. investors* variable is still positive and significant. Such loss in the significance of our coefficients could be explained by the importance of the variance of our variable of interest among our sample. Within the CVC sample, variance of institutional ownership variable is of 20.1% and its mean reaches 64%. As a consequence an increase of one standard deviation in the mean leads to an increase of approximately one third of its value. Such variance implies greater variance in the value fitted by our model and in the estimate too, which could lead to non-significant results.

Table 1.6: Instrumental variable methodology

	Full sample		CVC high		CVC low	
	<i>Instit.</i> (1)	<i>CVC_event</i> (2)	<i>Instit.</i> (3)	<i>CVC_event</i> (4)	<i>Instit.</i> (5)	<i>CVC_event</i> (6)
<i>S&P500</i>	5.443*** (0.809)		5.903*** (1.005)		5.116*** (1.368)	
<i>Instit. fitted</i>		0.049* (0.027)		-0.012 (0.026)		0.361*** (0.080)
<i>Firm Size</i>	-1.086** (0.465)	0.088 (0.069)	-0.768 (0.618)	-0.023 (0.082)	-1.614** (0.710)	0.509*** (0.188)
<i>ROA</i>	30.293*** (3.879)	-2.020** (1.012)	30.556*** (4.439)	-0.046 (1.012)	29.676*** (8.024)	-11.174*** (2.969)
<i>MtoB</i>	-0.077 (0.094)	-0.036** (0.017)	-0.294*** (0.114)	-0.053** (0.022)	0.080 (0.182)	-0.063 (0.039)
<i>HHI</i>	-4.408 (9.389)	2.604 (2.373)	93.974* (56.870)	12.667 (8.932)	-8.618 (9.890)	5.450* (3.311)
<i>Leverage</i>	-0.033 (0.191)	0.009 (0.027)	0.693* (0.363)	0.025 (0.057)	-0.180 (0.152)	0.066* (0.036)
<i>Log(1+Cash)</i>	0.171 (0.363)	0.138** (0.057)	0.135 (0.484)	0.020 (0.063)	0.574 (0.554)	0.320* (0.163)
<i>Log(1+R&D)</i>	-0.891*** (0.269)	0.599*** (0.060)	-1.357*** (0.449)	0.669*** (0.088)	-0.466 (0.354)	0.680*** (0.110)
Hausman test (p-value)	0.068		0.636		0.000	
Observations	4,734	4,734	2,650	2,650	2,084	2,084
R ²	0.272		0.226		0.329	
Adjusted R ²	0.260		0.217		0.307	
Log Likelihood		-1,577.688		-1,169.119		-366.393
Akaike Inf. Crit.		3,299.375		2,404.239		866.785

Note: This table presents the results of the instrumental variable methodology. S&P 500 is our instrument and is a dummy variable equal to one if the firm is included in the index in a year. The first column of each subsample analysis is the first-stage regression. In these regressions the dependent variable, *Instit.*, is the percentage of shares held by institutional investors. The other dependent variable, *CVC_event*, is a dummy variable equal to one if the firm has a CVC structure in year *t* and zero otherwise. *ROA* is the ratio of net income over total assets. *MtoB* is the ratio between the market capitalization and book value of equity. *HHI* is the Herfindahl index computed with two-digit SIC codes. *Leverage* is the ratio between long-term debt and total assets. *Log(1+Cash)* is the logarithmic value of cash available in the firm. *Log(1+R&D)* is the logarithmic value of Research and Development expenses available in the firm. Significance levels: *p<0.1; **p<0.05; ***p<0.01

5. Conclusion

Our paper shed light on the role of shareholders in shaping the innovation policies among the corporations. Our main result suggests that institutional investors have a positive influence on the opening of CVC structures within corporations. This result is robust to ownership concentration and a sample excluding periods of high CVC opening. Moreover, we find that this relationship is causal when applying the instrumental variable methodology suggested by Aghion *et al.* (2013). Such results are consistent with the literature on institutional investors. We interpret this positive influence of institutional investors as being caused by their long-term orientation, since it leads to an absence of short-term pressure on managers and better monitoring (Aghion *et al.*, 2013; Bushee, 2001, 1998).

We also performed an analysis on the typology of institutional investors following Bushee's methodology (1998). We find that institutional investors' influence is driven by quasi-indexers and dedicated investors. Dedicated investors are characterized by long term ownership and low diversification, while quasi-indexer hold highly diversified portfolios for a long period of time. We consider the latter investors as passive in the sense that they do not actively manage their funds.

Dedicated investors are particularly suited for monitoring managers according to their long-term and concentrated holdings. They also gather insider information and take decisions that do not only rely on performance. Moreover, they are considered as activist investors in the sense that they are able to intervene directly through a voice or exit mechanism. Dedicated investors are able to speak to the management during either formal (e.g. annual meeting, investor calls, etc.) or informal ways.

Quasi-indexers are more inclined to support long-term value creation projects according to their large and illiquid holdings. This creates incentives for long-term projects and innovation and fosters the opening of CVC structures. Our findings support the recent strand of literature on passive shareholders which argues that such investors are able to promote the value of the firm with a greater level of corporate governance practices (Appel *et al.*, 2016; Schmidt, 2017). Such investors could also facilitate activists' campaigns (Appel *et al.*, 2019) and support propositions made by dedicated investors to open a CVC structure.

Lastly, we consider that further research could improve our result based on the typology of investors by using a classification based at the fund level, instead of the institution level. Another possible path of further research could closely look at the mechanisms in place when

analyzing the quasi-indexers influence. One could be able to see if their influence is really based on their long term orientation, their support to activist's campaigns or a decrease in monitoring that managers can abuse.

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Appendices

Table 1.7: Pearson correlation matrix

	1	2	3	4	5	6	7	8	9	10	11
1 <i>Instit. Investors</i>	1.000										
2 <i>Dedicated Inv.</i>	0.251	1.000									
3 <i>Quasi-indexer Inv.</i>	0.929	0.059	1.000								
4 <i>Transient Inv.</i>	0.735	0.029	0.498	1.000							
5 <i>Firm size</i>	0.623	0.108	0.627	0.386	1.000						
6 <i>ROA</i>	0.292	0.011	0.308	0.175	0.390	1.000					
7 <i>MtoB</i>	0.080	(0.013)	0.036	0.156	0.030	(0.053)	1.000				
8 <i>HHI</i>	0.006	0.007	0.012	(0.010)	0.102	0.102	(0.068)	1.000			
9 <i>Leverage</i>	0.004	0.001	0.004	0.002	0.056	0.015	0.143	0.026	1.000		
10 <i>log(1+Cash)</i>	0.576	0.085	0.548	0.431	0.801	0.225	0.140	0.000	0.009	1.000	
11 <i>log(1+R&D expenses)</i>	0.431	0.059	0.423	0.298	0.539	0.039	0.191	(0.248)	(0.023)	0.654	1.000

Table 1.8: Spearman correlation matrix

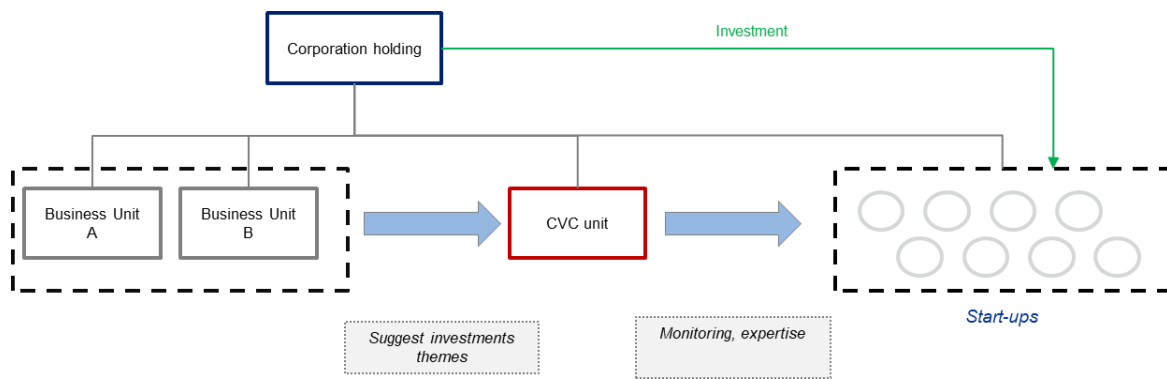
	1	2	3	4	5	6	7	8	9	10	11
1 <i>Instit. Investors</i>	1.000										
2 <i>Dedicated Inv.</i>	0.482	1.000									
3 <i>Quasi-indexer Inv.</i>	0.939	0.382	1.000								
4 <i>Transient Inv.</i>	0.807	0.327	0.640	1.000							
5 <i>Firm size</i>	0.659	0.381	0.662	0.514	1.000						
6 <i>ROA</i>	0.295	0.123	0.316	0.214	0.350	1.000					
7 <i>MtoB</i>	0.202	0.137	0.154	0.271	0.096	0.186	1.000				
8 <i>HHI</i>	(0.016)	(0.024)	(0.007)	(0.040)	0.061	0.152	(0.127)	1.000			
9 <i>Leverage</i>	0.143	0.105	0.169	0.047	0.404	0.079	0.048	0.130	1.000		
10 <i>log(1+Cash)</i>	0.599	0.335	0.563	0.543	0.755	0.233	0.248	(0.093)	0.082	1.000	
11 <i>log(1+R&D expenses)</i>	0.409	0.259	0.396	0.361	0.397	0.034	0.297	(0.364)	(0.055)	0.557	1.000

Table 1.9: Results with standard errors clustered at the industry level

Panel A: Baseline					
	Full sample (1)	Full sample (2)	Full sample (3)	Full sample (4)	No 2000's (5)
<i>Instit. investors.</i>	0.010*** (0.004)				0.010** (0.004)
<i>Top 10 Instit. inv.</i>		0.009* (0.005)			
<i>Top 5 Instit. inv.</i>			0.009 (0.006)		
<i>Top 1 Instit. inv.</i>				0.005 (0.011)	
Fixed effect	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	31,962	31,962	31,962	31,962	26,655
Log Likelihood	-2,924.00	-2,933.23	-2,935.80	-2,938.80	-2,508.05
Panel B: Investor type					
	Full sample (1)		CVC high (2)		CVC low (3)
<i>Dedicated Inv.</i>	-0.004 (0.014)		0.022 (0.019)		-0.037 (0.031)
<i>Quasi-indexer Inv.</i>	0.013*** (0.005)		0.012** (0.006)		0.012 (0.007)
<i>Transient Inv.</i>	0.005 (0.010)		0.009 (0.012)		-0.016 (0.028)
Fixed effect	Yes		Yes		Yes
Controls	Yes		Yes		Yes
Observations	31,962		19,817		12,145
Log Likelihood	-2,920.06		-2,182.68		-652.323
Panel C: Instrumental variable					
	Full sample (1)		CVC high (2)		CVC low (3)
<i>Instit. fitted</i>	0.050 (0.052)		-0.012 (0.033)		0.387** (0.155)
Fixed effect	Yes		Yes		Yes
Controls	Yes		Yes		Yes
Observations	4,734		2,650		2,084
Log Likelihood	-1,577.69		-1,169.12		-366.393

Note: This table presents the results with standard errors clustered at the industry level. Panel A describes the baseline results as well as main robustness tests. Panel B runs the models with distinct investors type. Panel C describes the result of the instrumental variable methodology. The dependent variable for all models is *CVC_event*, which is a dummy variable equal to one if the firm has a CVC structure in year t and zero otherwise. *Instit. Investors* is the percentage of shares held by institutional investors. *Dedicated Inv.* is the percentage of capital held by dedicated investors. *Quasi-indexer Inv.* is the percentage of capital held by quasi-indexer investors. *Transient Inv.* is the percentage of capital held by transient investors. *Firm size* is the log of total assets of the firm. *ROA* is the ratio of net income over total assets. *MtoB* is the ratio between the market capitalization and book value of equity. *HHI* is the Herfindahl index computed with two-digit SIC codes. *Leverage* is the ratio between long term debt and total assets. *Log(1+Cash)* is the logarithmic value of cash available in the firm. *Log(1+R&D)* is the logarithmic value of Research and Development expenses available in the firm. Significance levels: *p<0.1; **p<0.05; ***p<0.01

Figure 1.3: Detailed functioning of a CVC structure



Source: Author, based on extensive reading of the literature and interviews with CVC fund managers

Chapitre 2. Do boards of directors encourage innovation? Evidence from publicly traded US firms

Abstract

This paper studies the influence of boards of directors on corporate innovation through their advisory capabilities. We use three types of variables to proxy for advisory: industry expertise, past experience, and network. We find a positive relationship between advising and corporate innovation, which stems mainly from directors' networks. Industry expertise and experience variables show evidence of a significant impact but have a smaller economic influence. Comparing the two types of directors, we find that outsiders promote corporate innovation through their network while insiders through their previous experience and expertise in the industry. Lastly, we analyze firms based on their characteristics (size, leverage, and R&D intensity). Consistent with the literature we find that insiders promote innovation in more complex firms that are expected to have a greater demand for advising. On the contrary, outsider advising plays a significant role in innovation independently from the complexity of the firm. This paper shows the dominance of network effect in reducing the uncertainty and transaction costs related to innovative activities thanks to the collection of valuable information and opportunities.

1. Introduction

Both functions of a board of directors (e.g. monitoring and advising) rely on distinct theoretical frameworks and intent on maximizing a firm's value. According to agency theory (Jensen and Meckling, 1976), the monitoring role of the board aims to align the interests of the shareholders, the CEO, and the managers in order to improve the firm's performance. The advisory role of the board is complementary to the agency theory and is related to the resource dependence theory of the firm (Pfeffer and Salancik, 1978). According to this theory, boards of directors are useful in managing external dependencies and reducing uncertainty and transaction costs associated with environmental interdependencies (Williamson, 1984) thanks to their expertise, experience, networks, etc. Such resources are particularly useful in shaping the strategy of the corporation and enhance its performance.

Innovation provides an insightful framework for studying the board's role and its influence on a firm. Innovation policy shapes the future strategy and growth of a company but its output is rather unpredictable and implies allocating significant corporate resources. Moreover, tolerance for early failure is essential in innovation processes (Manso, 2011). Consequently, managers of a firm may refrain from investing in innovation activities in order to limit risk-taking and to minimize the possibility of being fired (Holmstrom, 1989). Innovation might also be reduced due to managerial myopia (Bushee, 1998; Porter, 1992). Lastly, the amount of input and the success of innovation depends on the quality of the managing team as well as technological knowledge (Chemmanur *et al.*, 2019). In an innovation context, a board can either monitor the managers in order to "force" them to promote innovation, or advise them to reduce uncertainty and the inherent risks of such activity.

In this paper we define innovation by its amount, quality, and type. We consider the amount of innovation by computing the number of patents applied by a firm and effectively granted a few years after. Quality of innovation is proxied by a variable measuring the number of citations received by the patents of a firm. As it is mandatory for every applied patent to cite previous patented work, such variable measures the importance and thus the quality of a patent. A highly cited patent means that it is relevant to several patents. Lastly, we work on the types of innovation by studying if the patents applied are considered explorative or exploitative. Explorative innovation is considered riskier than exploitative innovation since it is related to technological areas unknown to the firm.

Literature has studied the linkage between monitoring and innovation through the ratio of independent directors on the board⁸. Such publications show a positive relationship between the presence of independent directors on the board and innovative output. The presence of independent members on the board increases the number of patents and citations especially when the company is in need of increased monitoring (Lu and Wang, 2018).

Balsmeier *et al.* (2017) find a similar result but they also show that board independence promotes exploitative rather than explorative innovation. This is because increased monitoring exacerbates the risk of dismissing the CEO for poor performance. Consequently, managers of the firm will be more risk averse and focus on quantifiable results (e.g. exploitative innovations).

The advisory capability of the board is harder to measure as it has several dimensions. Literature often uses variables describing the directors' level of expertise, past experience, and connections to proxy the advisory role of a board. Consequently, common variables typically measure the number of years directors have been serving on a board or working in the industry, which position they occupied, and the number of relations they have to other senior executives. Overall, these papers support the idea that the advisory capacity of the board has a positive influence on corporate innovation.

However, such papers study the relationship using advising measures distinctively and focus on a single dimension of advisory capability. For instance, papers will only study the impact of board members' networks on innovation. Moreover, published papers tend to focus on a certain type of director (i.e. independent or the CEO predominantly)⁹.

We believe independent directors and insiders are equally important in terms of advisory capability. The role of independent directors is clear in terms of advising: although they do not know the firm as well as the insiders, they sit at many different boards which enables them to gather a broader knowledge. However, insiders can also play a role in shaping the innovation strategy of a firm. The time they spent in a company or in an industry as well as their network enable them to gather specific knowledge that can be valuable in an innovative context. Furthermore, we believe directors have access to different information, knowledge, and

⁸ Independent directors have no material or pecuniary relationship with the firm or the executives. Such directors do not have an operational role in the firm. They are often called outsiders (Weisbach and Hermalin, 1991) and opposed to insiders, who are directors that are employed by the firm and thus, have a managerial role in it.

⁹ See Chang and Wu (2020); Custódio *et al.* (2017); Faleye *et al.* (2014)

expertise according to their type. This could indicate a difference in their influence on corporate innovation.

The first question we aim to answer in this paper is whether the advisory role of the board can lead to more and higher quality innovations. We also study which type of innovation (e.g. explorative or exploitative) is influenced by the board. Going further, we wish to fill a gap in current literature by examining both insider and outsider roles in innovation in order to detect if one type of director is better suited to promote innovation. Additionally, we try to identify which aspects of advising are more important for enhancing innovation. To do so we use four measurements of board advising that we distinguish for outsiders and insiders. For each firm we compute the sum over directors of the number of years they served in the industry of the firm they are at the board (*Industry Expertise*). We calculate the ratio of board members that worked in financing, law or public relation companies (*Support Specialist*) as well as the ratio of board members that worked in a public institution or had political experience (*Community Influential*). Lastly, we sum, over the directors, the total number of connections they have (*Network*).

Additionally, we try to investigate potential mechanisms by which board composition influences innovation. We focus on the assumption that firms need more advisory as they become more complex (Coles *et al.*, 2008) and face monitoring issues. Consequently, we compose three subsamples that describe respectively, the size of the firm, the leverage ratio and the intensity of R&D expenses. As the firm gets bigger, more indebted and more R&D intensive, it should increase its demand for advising and monitoring and consequently, the influence of directors should increase in such firms.

Using a dataset merging BoardEx, innovation data¹⁰ and Compustat over the period 2000-2007, we find evidence that the advising capabilities of both outsider and insider directors positively influence corporate innovation in terms of quantity and quality. This effect mostly stems from the directors' networks. We find evidence for the variables related to their experience and industry expertise, but their economic influence seems to be lower. Our results are consistent with the interpretation that networks provide top management with valuable information and enhance its ability to identify and exploit innovation opportunities. Such mechanisms reduce

¹⁰ We use the dataset developed by Kogan *et al.* (2017) as our innovation dataset (henceforth KPSS).

managerial risk aversion by diminishing ex-ante riskiness of innovation projects (Faleye *et al.*, 2014).

Our results also show that insiders and outsiders influence innovation thanks to different resources. The former have a positive influence on innovation through their expertise in the industry, while their network has a limited statistical significance. On the contrary, outsiders see their experience variables not statistically significant but have a strong influence through their network. In the end, the board is able to promote corporate innovation by providing a mix of in-depth expertise in the industry, which provide specific knowledge, and out-of-the-box ideas generated by the network of independent directors.

When studying innovation strategies, we find only limited evidence of the positive impact of board advising capability on explorative innovation. Relative to insiders, their expertise in the industry and their past experience in a public institution are the only variables statistically significant. Concerning, outsiders, only their network plays a positive role on explorative innovation.

Such findings suggest that insiders do not enjoy labor market insurance because of their network, as suggested by Faleye *et al.* (2014). According to the authors, a CEO's network reduces the risk of being unemployed after the failure of an innovative project, thus allowing the CEO the freedom and assurance to invest in innovative activities. However, our results show that insiders' networks are not associated with an increase in explorative innovation, implying that the presence of a labor market insurance does not hold.

When focusing on the potential mechanisms of influence and realizing a subsample analysis based on the size and the leverage ratio of firms we find divergent results for insiders and outsiders. The effect of insider advising increases as the firm gets larger and more indebted and mostly comes from their expertise. As expected, we find a positive influence of independent directors' networks in large and highly indebted firms. Such firms are considered as more complex and have a high demand for advising.

Furthermore, when realizing this analysis, we also find a positive influence from independent directors on innovation in small and lowly indebted firms. We interpret this finding by stating that less complex firms are less connected to their environment and they benefit more from independent directors than insiders, since such firms are less able to collect information and opportunities of innovation through their executives.

Lastly, for R&D intensive firms we show a positive and significant effect of insiders: their expertise and network play a significant role in corporate innovation of R&D intensive firms only. This is consistent with the idea that such companies are in greater need of advice in terms of industry-specific knowledge. Interestingly, we find that outsiders also play a role in corporate innovation through their network in both intensive and non-intensive R&D firms. Outsiders are able to provide valuable information to managers of the firm even if the firm is already considered as innovative.

This paper contributes to the literature in several ways. First, in running regressions with several dimensions of advisory capability we show that a director's network is the dominant dimension that influences corporate innovation. The expertise gathered in specific sectors or the ability to secure external commitment do play a role in shaping innovation among firms but their economic impact is rather limited. It is the ability of the director to connect firms between them and have access to information and opportunities that positively influences innovation. We also add to the literature by finding that both types of directors have a positive influence on corporate innovation with distinct effects. In general, insiders have an impact on innovation through their expertise while outsiders through their network. This suggests that different types of information and opportunities are gathered through different networks and influence corporate innovation differently.

The paper proceeds as follows: Section 2 describes the related literature and develops our testable hypothesis; Section 3 details our variables construction and our empirical methodology; Sections 4 and 5 describe the results obtained and the robustness tests realized; finally, Section 6 concludes the paper.

2. Literature review

In this section, we describe the literature related to our grounded research question and develop several testable hypotheses. We review the literature on the influence of the board composition on corporate innovation through its monitoring and advisory roles.

2.1. Board and corporate innovation

Theoretically, a board's advisory role draws from the resource dependence theory of Pfeffer and Salancik (1978). In this theory, firms are dependent on external factors that are beyond their control. Such dependency generates risk and uncertainty for the firm. A common example for illustrating this theory is the customer-supplier relationship. To produce its output, the customer is dependent on the supplier. A customer firm will face uncertainty concerning the price, the quality, or the delivery period of the raw material. Firms will try to diminish these uncertainties by reducing their dependency on external factors. Common solutions include the integration of such external factors (e.g. acquisition of the supplier firm).

In the resource dependence theory, directors play a particular role in the sense that they link firms between them by sitting on the board of multiple firms. Directors serve as an interface between a firm and its external dependencies. This allows the directors to reduce uncertainties and transaction costs the firm may be facing (Williamson, 1984). By sitting on multiple boards, directors accumulate knowledge, skills, information or contacts with key constituents (suppliers, clients, public policy decision maker, etc...). Such resources, when brought to the firm, allow the directors to reduce costs related to prospecting, research, or unknown processes.

For instance, the presence of a director with previous experience in finance or law can reduce uncertainty by bringing information and expertise from these areas. For a firm seeking external financing, such a director will be able to reduce the transaction costs by using their network and influence to facilitate financing.

In an innovation context, a firm faces uncertainties about the outputs of its activities not only due to the inherent riskiness of innovation but also due to regulations (delay of patent grant, differences in patenting process over countries, litigation) or competition. Additionally, innovation strategies often imply the spending of significant resources and investing in specific assets. Uncertainty and specificity of assets increase the transaction costs of a firm. According

to the resource dependence theory, directors may be able to cope with such issues and enhance innovation within the firm thanks to their advisory capabilities.

We decline such advisory capabilities into four distinct variables that are found to have an impact on either the corporate innovation or the strategy of the firm.

The most common measure of advising is a director's network (i.e. the number of people to whom a director is connected according to the previous positions they held). Coles *et al.* (2012) find a positive relationship between independent directors' connections and a firm's performance. Faleye *et al.* (2014) focus on the connectedness of the CEO and find a positive and significant relationship with innovation. Helmers *et al.* (2017) find that board interlocks have significant positive effects on both R&D and patenting, suggesting that information can be transmitted via shared directors. Lastly, Chang and Wu (2020) find that an increase in directors' networks leads to a greater level of corporate innovation.

Other measurements relate to a director's past experience. Hillman and Dalziel (2003) identify four types of directors: support specialists, community influentials, insiders, and business experts. Each type of director has specific knowledge about the firm, the industry, or particular processes. Support specialists are directors who provide in-depth expertise in areas of law, finance, insurance, and public relations. Community influentials are directors providing non-business perspectives to issues the board may face. They are typically connected to decision-makers in society or government. Such directors are former political leaders, university faculty, or members of community organizations. Insider directors are defined as current and former officers of the firm and gather knowledge about the firm's operations and strategy. Finally, business experts are categorized as current or former officers of other companies. They have a similar knowledge as insiders but in a different firm or industry. By mixing heterogeneous profiles and combining expertise, a board of directors helps a firm to respond to significant changes in its external environment (Haynes and Hillman, 2010; Hillman *et al.*, 2000; Hillman and Dalziel, 2003).

Lastly, a director with experience in a firm or an industry may be able to anticipate outcomes and reduce risk in situations of high uncertainty, thereby delivering better performance. Kempf *et al.* (2017) and Pástor *et al.* (2015) demonstrate this in their papers on fund performance. Experienced directors may have learned from their experience which kinds of innovation strategies work best for the industry and how to implement them. Such knowledge is useful in providing advice to improve innovation performance and increase corporate innovation. Kang

et al. (2018) find a positive relationship between innovation and the presence of independent directors with CEO experience in the same industry.

These elements allow us to make the following assumption:

H1: All elements of directors' advisory capabilities (i.e. expertise in industry, past experience, and network) are positively associated with corporate innovation.

In the literature, outsiders are considered as monitors and advisors of the CEO for business strategy, while insiders formulate the firm's strategy and communicate information about the firm to outsiders (Jensen, 1993). Therefore, the advisory role is dominant for independent directors. Due to such findings, we expect that outsiders and insiders influence innovation differently.

The monitoring role of outsiders could be expected to induce pressure on the CEO to provide quantifiable results and reduce radical innovation (Balsmeier *et al.*, 2017); however, thanks to their broader knowledge and access to valuable opportunities, independent directors could be better at advising firms that seek radical and out-of-the-box ideas. Such innovations are defined as exploratory by the literature.

Insiders are typically more embedded to their industry and develop an in-depth expertise in it. Literature has found that a greater level of industry expertise would harm exploratory innovation (Custódio *et al.*, 2017) and strategic change (Haynes and Hillman, 2010). According to researchers, managers of the same industry share common knowledge, perception and belief about the industry. As a consequence, as an individual is embedded in its industry, the more the individual could take decisions that are considered the norm in the sector, thus reducing the possibility to choose alternative solutions and take greater risks.

We chose to test whether outsiders are effectively better at promoting riskier innovation than insiders and formulate the following hypothesis:

H2: Independent directors' advising is more important for explorative innovation strategies than insiders'.

2.2. Increased demand for advising: complex and R&D intensive firms

Firms may interact differently to their external dependencies and may be more prone to being resource dependent than others. For instance, diversified firms operate in many different segments which increase the number of external relationships. Similarly, a firm with a high leverage ratio indicates a dependency on external resources as well as monitoring needs.

This implies that different types of firms may have different needs in terms of advising. A strand of literature has studied the requirement of complex firms in term of board and their increased advising needs due to a greater dependency on external resources¹¹. Coles *et al.* (2008) argue that complex firms (i.e. diversified, large and indebted) will have a larger board, with a significant number of outsiders in order to satisfy their advising needs. In a second paper, Coles *et al.* (2012) find a positive relationship between firm complexity and advisory quality (proxied by the size of outsider's network) and quantity (proxied by the number of outsiders sitting at the board). Similarly, Chang and Wu, (2020) find that board networks are more important in nurturing innovation among firms that have great advising needs (i.e. firms with diversified activity, high R&D intensity and volatile cash flows).

Therefore, we are able to make the following assumption:

H3: Directors' advisory capabilities have a larger effect on innovation in firms having a greater external resource dependency.

Firms having significant R&D programs are characterized by a greater level of uncertainty due to the specificity of the knowledge and investments implied (Faleye, 2007). Consequently, such firms face high project verification costs. Insiders, who are better informed as to the quality of a firm's investment projects, are good candidates to manage such projects and reduce uncertainty. The literature seems to agree with this intuition: insiders are more represented on the board of such firms (Raheja, 2005). In R&D intensive firms, insiders may be able to give better advice to the firm than outsiders and have a greater influence on corporate innovation thanks to their knowledge and experience. According to Baysinger *et al.* (1991) and Fama (1980) such directors are better positioned to select appropriate strategies.

¹¹Hermalin and Weisbach (1988); Klein (1998); Rose and Shepard (1997)

Following the literature, we wish to identify if insiders do influence corporate innovation and by which mean. Therefore, we make the following testable assumption:

H4: Insiders' advisory capabilities positively influence the outcome of innovation among R&D intensive firms.

3. Empirical methodology and sample construction

Our sample is composed of public North American firms between the years 2000 and 2007. We used several databases to construct this sample and compute our variables related to innovation, advising, and accounting.

Data related to boards of directors was downloaded from the BoardEx database. Innovation data comes from the work of Kogan *et al.* (2017)¹² who provide an enhanced version of the UPTSO patent database. They extended the dataset until 2010 (vs. 2006 for UPTSO) and succeeded in assigning patents to companies from 1926 onwards with a unique identifier (e.g. the permno used in CRPS), which enables us to easily merge the data with other databases. KPSS database provides data with annual records of both the citing and cited patent number, the date when the patent application was filed and issued, as well as the technological area of the innovation. Lastly, we used Compustat for accounting and financial data relative to the firms.

3.1. Innovation variables

Using the KPSS database, for each year and for each firm, we computed the number of patents applied (*Patents*) and their number of future citations (*Cites*). Furthermore, following the methodology of Lu and Wang (2018) we computed a weighted measure of the citations received. To do so we took the number of citations a particular patent received and divided it by the total number of all patent citations in the same technological class¹³ during the same year. This was then summed at the firm level (*Cites weighted*). This weighting scheme is particularly important as the number of citations accumulates over the course of a year.

¹² Henceforth abbreviated KPSS

¹³ Technological classes are defined by the USPTO and are already present in the database.

Consequently, patents granted at the end of the sample period have less time to accumulate citations than prior patents. This measure is an alternative of the method of Hall *et al.* (2005) to control for time-fixed effects of patent application.

Following Balsmeier *et al.* (2017) we also computed various measures of innovative activity in order to identify the explorative and exploitative aspect of innovation. We computed the sum of patents filed in classes that are unknown and known to the firm. Unknown classes are defined as classes in which a firm has not previously applied for patent. We consider that firms with patents in unknown technology classes are taking greater risks than firms developing patents in already known classes. A patent in an unknown class is more prone to become a radical innovation and implies research in areas with which the firm is unfamiliar. On the contrary, patents applied in known technological classes indicate research in similar fields to the firm and is typically related to incremental innovations.

In an attempt to identify the power and quality of a patent with respect to innovation, we categorized patents based on the number of citations they received in a year and in the same technology class. We define these categories using the distribution of patent citation for each year and technology class. Patents fall into four distinct categories: top 1%, 2nd-10th%, not in the top 10% but cited at least once, and never cited at all. By running a different model for each category of patent, we will be able to identify whether the advisory role of the board is able to promote successful innovation (highly cited) or unsuccessful innovation (uncited patents).

We also computed the number of self-citations that each patent receives. We consider a self-citation as a citation made by a patent that belongs to the same firm. A patent with a high self-citation number indicates a narrower area of research and development than patents with low self-citations numbers.

3.2. Advising measures

Our paper measures three aspects of directors' advisory capabilities: expertise in the industry, past experience, and network. To compute these variables we used the Employment files available through BoardEx. These files trace the various positions each director held, from the senior manager position to executive directorship, as well as the independent director position. The measures presented below were first computed at the director level, then aggregated at the

firm level. For each measure of advising, we computed two distinct variables given the type of the director (i.e. outsider or insider).

Our proxy for industry expertise is computed as the number of years that a director worked in the industry of the firm on whose board he is sitting. Such a proxy captures the operational knowledge of the director in specific industries and firms.

Past experiences of director's proxies were based on the taxonomy defined by Hillman *et al.* (2000). We categorize a director as either a *Support Specialist* or a *Community Influential*. According to the authors, *Support Specialists* provide expertise and linkage in specific areas that support the firm's strategies but do not form the foundation on which the strategy is built. Such directors support management in areas such as capital markets, banking, law, insurance, and public relations. This type of director reduces risk related to these supporting areas, thereby allowing the company to allocate more time and resources to innovative activity. This is done by securing commitments from external organizations (Pfeffer and Salancik, 1978) and by lending legitimacy to the firm. For instance, a director who is also a member of a financial institution may help communication between a firm seeking capital and capital suppliers. We categorized *Support Specialists* as directors that ever had an experience in the following sectors: finance, law, and public relations¹⁴.

Community Influentials are directors whose knowledge is relevant to a firm's environment beyond competitor firms and suppliers. They typically have experience in governments, universities, or other institutions and social organizations. Such directors provide the board with non-business perspectives and recommendations for strategic orientation. We identified directors as *Community Influentials* if they ever had an experience in a government, university, or charity.

Because we look at the whole career of directors, it is possible that they are considered as both *Support Specialists* and *Community Influentials*.

The taxonomy of Hillman *et al.* (2000) defines another type of director: *Industry Expert*. It indicates whether the director previously worked in the industry of their current firm. However,

¹⁴ We do not take into account directors that have an experience in Human Resources, even though this sector may be relevant for a company in selecting the right profile for a position. The reason is that the dimension of the quality of the people recruited depends on their experience and expertise and those elements are already captured in other advisory variable.

we chose not to include this in our analysis. We consider this definition too broad, since the number of directors working in different firms or in different industries is high. Such a variable, therefore, would not be determinant in our regressions. Moreover, including this variable would induce collinearity issues when computing the ratio for outsiders and insiders. In the case of a company in which all directors worked in a different company, the ratio of outsiders having experience in the industry would be the exact opposite of the same ratio for insiders.

We compute the network of directors using the network files made available in BoardEx. Such files, for every director present in the database, lists all the connections they have with other directors and senior managers in any organization (clubs, companies, etc.). We follow the methodology of Chang and Wu (2020) to count the number of connections for directors. Directors share a connection if they were or are currently employed in the same organization at the same time. Our measure of network takes into account connections made through employment in private or public firms as well as non-business organizations (e.g. sports clubs, charities, etc.). For the latter type of connection, we require that both individuals connected play an active role in their organization. Therefore, we exclude connections if they are simply “members” of an organization. We also make sure not to double count connections in case directors know each other through their employment and their charity.

Lastly, we use the BoardEx variable *Director Role* to identify whether the director is independent (i.e. outsider) or not (i.e. insider).

Since our sample is at the firm level and the aforementioned variables are at the director level, we need to aggregate them. More specifically, we aggregate them separately for each type of director. *Industry Expertise* is computed as the sum of years worked in the industry among all the directors sitting on the board. *Support Specialists* and *Community Influentials* are computed as the ratio of such directors type divided by the number of directors on the board. *Network* compute the sum of the connections of directors on the board. Finally, for regression purpose and in order to follow the literature we use the log of one plus the number of connections as a variable.

3.3. Controls

We incorporated accounting data relative to the firms in the sample. We used the annual filing of the Compustat database to download the following variables for the sample period: total assets, net income, R&D expenses, long-term debt (current and non-current amounts), shareholder equity, and market capitalization of the firm.

This data allows us to compute the following variables:

- Leverage ratio computed as the ratio between long-term debt and shareholder equity;
- Return on asset, computed as the ratio between net income and total assets;

We use logarithmic value for the total assets and R&D expenses variables.

Our last control variable computes the number of directors sitting at the board of the firm (*Board size*) as provided by BoardEx.

3.4. Empirical specification

We merge our different databases using the CIK identification number provided by the BoardEx database. This identification number is also present in the Compustat database. In order to merge our data with the KPSS database, which uses the permno as an identification number, we create a link table that associates each CIK number with the permno codes of a firm. This table was created with Compustat. As a result, we have 6,501 observations for 1,707 unique firms in our sample.

In order to identify how a board's composition influences corporate innovation, we run regressions with distinct variables for outsiders and insiders. Our regressions are run with OLS fixed-effect models for each innovation measure (i.e. number of patents and citations). The main model used in the paper is the following:

$$\begin{aligned} Innovation_{i,t+1} = & \alpha + \beta_1 * Outsider\ variables_{i,t} + \beta_2 * Insider\ variables_{i,t} \\ & + Controls_{i,t} + \varepsilon_{i,t} + \mu_t + \mu_s \end{aligned} \quad (2.1)$$

Outsider and insider variables are a combination of *Industry Expertise*, *Support Specialist* ratio, *Community influential* ratio, and *Network*. In order to control for potential heteroscedasticity in the variance of our variables, we run our models with year (μ_t) and industry fixed effects using two-digit SIC codes (μ_s) and we cluster standard errors at the firm level.

We use the log value of innovation variables and lag them by one year in order to take into account a degree of causality in our analysis. All innovation variables are computed from the application date of the patent instead of the grant date because it is considered closer to the actual innovation made by the company.

3.5. Descriptive statistics

Table 2.1: Descriptive statistics

Variables	Unit	Obs.	Mean	ST. Dev.	Skewness	Kurtosis	Min.	Max.
<i>Patents</i>	#	6,501	42.0	190.6	12.2	192.1	1.0	4,397.0
<i>Citations</i>	#	6,150	212.0	1,270.4	18.1	489.3	-	49,154.0
<i>Citations weighted</i>	#	6,136	47.5	197.1	11.0	157.0	-	4,240.2
<i>Industry Expertise_outsider</i>	Years	6,501	48.0	32.2	0.9	0.9	-	202.0
<i>Industry Expertise_insider</i>	Years	6,501	29.1	26.4	2.1	7.2	-	272.0
<i>Support Specialist_outsider</i>	%	6,501	18.2	17.4	1.1	1.3	-	92.9
<i>Support Specialist_insider</i>	%	6,501	3.9	8.4	3.4	17.4	-	100.0
<i>Community influentials_outsider</i>	%	6,501	10.9	12.1	1.0	0.5	-	63.6
<i>Community influentials_insider</i>	%	6,501	2.2	5.4	2.8	9.3	-	50.0
<i>Network_outsider</i>	Thousands	6,501	3,158.9	2,887.1	1.7	4.0	-	24,150.0
<i>Network_insider</i>	Thousands	6,501	818.2	1,163.0	3.6	20.3	-	13,209.0
<i>Firm size</i>	log	6,501	6.7	2.1	0.3	0.1	(0.7)	14.4
<i>ROA</i>	%	6,501	(0.0)	0.3	(10.5)	229.7	(11.1)	1.6
<i>Leverage</i>	%	6,501	0.4	0.6	2.3	7.4	(1.8)	3.7
<i>R&D expenses</i>	log	5,568	3.6	1.8	0.1	0.6	(4.6)	9.4
<i>Board Size</i>	#	6,501	8.6	2.5	0.9	1.4	3.0	24.0

The sum of years worked in the industry of the firm at which they are sitting reaches 47.5 years for outsiders and 29.1 years for insiders, although we would have expected the reverse. However, this is not surprising as the number of outsiders exceeds insiders. Therefore, since our measure is computing a sum over the directors, it is normal that our variable is higher for outsiders than insiders. In unreported results, we compute the average values of industry expertise relative to the type of director and find that, on average, outsiders worked 8.9 years

in the same industry of the company, while insiders worked 14.2 years. This is consistent with our expectations.

There are more *Support Specialists* and *Community Influentials* among outsiders than among insiders. Lastly, it appears that the network of independent directors (3.2k individuals) is larger than insiders' networks (1.0k individuals). Because outsiders sit at more boards than insiders throughout their career it is consistent that their networks are higher. Consequently, outsiders have a higher probability of having experience in support sectors and of being more connected to other directors. These differences in descriptive statistics suggest that each type of director can influence corporate innovation differently.

Overall, our sample is composed of relatively large firms as the average of the log of assets is equal to 6.7, equivalent to \$812.4m of total assets.

All the definitions of the variables used in this paper are presented in the appendix as well as the correlation matrices.

4. Main empirical results

In this section, we describe and comment on our baseline results, the impact advising has on the types of innovation, and our subsample analysis.

4.1. Board characteristics and their influence on corporate innovation

This section presents the baseline results of the paper. Table 2.2 describes the influence of advisory capability variables on each measure of corporate innovation (i.e. the number of patents applied by a firm, the number of citations received, and the weighted value of citations received). These models are estimated with OLS methodology.

The time that outsiders spent working in the industry does not seem to play a role in corporate innovation, as there are no significant coefficients associated with the variable *Industry Expertise_outsider*. On the contrary, *Industry Expertise_insider* is positive and significant in the model with citations as independent variables (columns 2 and 3). Every other variables hold equal, an increase of one year of expertise in the industry from insiders would increase the average number of citations by 0.005 citations.

Similarly to *Industry Expertise*, the previous experiences of outsiders have only a limited effect on corporate innovation: *Support Specialists* variable is not significant in any model estimated. However, the variable for insiders has a negative and significant coefficient in every model estimated. Every other variable hold equal, the increase of one percent in the variable would decrease the average number of citations by 0.013 citations.

Community Influentials_outsiders is only significant in the model based on the number of patents applied. The increase of one percent of the variable, if every variable holds equal, would lead to an increase in the average number of citations by 0.007 citations. *Community influential_insider* variable has no significant coefficient in our models.

The *Network_outsiders* variable shows a positive influence on corporate innovation. Independent directors' networks increase innovation through higher quality patent thanks to a positive coefficient associated with the $Cites_{t+1}$ and $Cites\ weight_{t+1}$ variables. The size of insider directors' networks plays a positive and significant role in the innovation output of a firm. Our models show positive and significant coefficients for the number of patents. Our results are economically significant as an increase from the 25th to the 75th percentile of board network increases the number of citations received by 39.8% from its mean, every other variable held constant¹⁵. When applying the same methodology for the *Industry Expertise* of insiders we find that an increase from the 25th to the 75th percentile increases the number of citations by 14.6% from its mean, every other variables held constant¹⁶.

Our results illustrate that a director's past experience has a limited impact on corporate innovation. Having an industry specialist on the board plays only a moderate role on corporate innovation at best. Therefore, gathering knowledge about a specific sector does not seem to be the best way to reduce uncertainty of innovative projects and promote corporate innovation. This is consistent with the findings of Custódio *et al.* (2017) who study the experience profile

¹⁵ We follow the methodology of Chang and Wu (2020) and Chang *et al.* (2015) for this computation. Because of the following: $\frac{d[Ln(1+y)]}{d[Ln(1+x)]} = \frac{1+x}{1+y} * \frac{dy}{dx}$, we can have the following expression: $dy = \frac{d[Ln(1+y)]}{d[Ln(1+x)]} * \frac{1+y}{(1-x)} * dx$. Therefore, when we compute the effect of an increase in *Network outsiders* (dx) on *Citations* (dy), we increase *Network outsider* from its 25th percentile (1,036) to its 75th percentile (4,397), so $dx=3,361$. The change in *Citations* from it mean value (212) is equal to $0.120 * \frac{1+212}{1+1,036} * 3,361 = 82.8$, which is equal to 39.1% of the mean of the *Citations* variable.

¹⁶ Because $\frac{d[Ln(1+y)]}{dx} = \frac{1}{1+y} * \frac{dy}{dx}$, we can write, $dy = \frac{d[Ln(1+y)]}{dx} * (1 + y) * dx$. Therefore, the change in *Citations* from it mean value (212) is equal to $0.005 * (1 + 212) * (39 - 10) = 30.9$, which is equal to 14.6% of the mean of the *Citations* variable.

of the CEO and oppose generalist to specific competencies. According to the authors a CEO with general managerial skills is better at innovating than a CEO with specialized skills. Such a phenomenon is due to greater tolerance for failure and more knowledge brought to the firm by generalist directors. The same mechanism seems to apply to our study on the network of directors considering if they are independent or insiders.

Having directors that secure external commitments (measured by the *Support Specialists* variable) indicates neither a greater level nor a greater quality of corporate innovation. On the contrary, the estimated coefficients are negative when significant, although their impact is not economically significant. Such findings suggest that an increase, at the board level, of the percentage of insiders with a past experience in law, finance or public relation companies, does not induce the firm to allocate more resources and time to innovative activities in order to increase its output. However, our expectation of a positive effect of such directors on innovations can prevail. As our variable measures a percentage, our results only tell us that more support specialists on a board is not positive for innovation. If we used a dummy variable for the presence of at least one support specialist director, we may have found a positive coefficient.

Lastly, non-business perspectives and advising brought by *Community Influentials* does not increase corporate innovation. These findings suggest that uncertainties related to innovative projects are not reduced through experience in non-business organization but rather with operational and business information.

A director's network, however, is found to play a positive and significant role in corporate innovation. The size of a director's network is an assessment of the quality of the director. The more the director is considered competent and valuable, the more companies will appoint them, which will lead in an increase of their network (Coles *et al.*, 2012).

Moreover, the network proxies a director's ability to access information that may be relevant for the company and its innovative projects. Access to information has an ex-ante and ex-post effect on corporate innovation. Acquiring relevant information prior to a project can help firm managers reduce information asymmetries and the inherent riskiness of innovative projects. The more a director is connected, the more information and opportunities they will be able to bring to the firm. Ex-post effect of directors' networks relates to the presence of a labor market insurance in the case of innovation failure (Faleye *et al.*, 2014). Since innovation implies the consumption of significant corporate resources, a failed project could hinder the firm's

performance and could result in the CEO's dismissal. However, a CEO could use their network to find a position in another firm. Therefore, well connected CEOs and insiders enjoy labor market insurance and have incentives to invest in risky projects such as innovation.

We also find a different influence on corporate innovation from the network depending if the directors are insiders or outsiders. Insiders only play a significant role on the quantity of innovation and not the quality of it. It is the opposite for outsiders: they have a positive influence on the citations of patents but not on the number of patents. This suggests that insiders are able to promote more patents but not with better quality while outsiders increase the quality of the patents applied. Everything works as if insiders generate ideas that are improved by outsiders. Information collected through different network types are relevant for reducing the uncertainty of innovative projects.

Lastly and more globally, our results show that insiders play a role in corporate innovation through their past experiences (i.e. industry expertise and experience in support sectors) rather than their network. On the contrary, for outsiders, the influence of their network prevails over their experience.

Our baseline results validate our *H1* hypothesis and reveal a positive correlation between directors' advising capability and corporate innovation. Our results also show that a board's advisory capabilities influence innovation depending on whom the directors worked with more so than where they worked.

Table 2.2: Board advisory capability and innovation output

	<i>Patents_{t+1}</i>	<i>Cites_{t+1}</i>	<i>Cites weight_{t+1}</i>
	(1)	(2)	(3)
<i>Industry Expertise_outsider</i>	0.001 (0.001)	0.0004 (0.001)	0.001 (0.001)
<i>Industry Expertise_insider</i>	0.001 (0.002)	0.005*** (0.002)	0.004*** (0.002)
<i>Support Specialist_outsider</i>	-0.001 (0.002)	-0.002 (0.003)	-0.001 (0.002)
<i>Support Specialist_insider</i>	-0.011** (0.005)	-0.013** (0.006)	-0.010* (0.006)
<i>Community influentials_outsider</i>	0.007*** (0.002)	0.002 (0.003)	0.002 (0.003)
<i>Community influentials_insider</i>	0.005 (0.005)	0.004 (0.006)	0.003 (0.006)
<i>Network_outsider</i>	0.033 (0.024)	0.120*** (0.034)	0.109*** (0.031)
<i>Network_insider</i>	0.045*** (0.017)	0.020 (0.023)	0.027 (0.022)
<i>Firm Size</i>	0.149*** (0.034)	0.123*** (0.047)	0.123*** (0.042)
<i>R&D</i>	0.422*** (0.032)	0.495*** (0.043)	0.464*** (0.039)
<i>ROA</i>	0.019 (0.074)	0.065 (0.113)	-0.0001 (0.101)
<i>Leverage</i>	-0.121*** (0.045)	-0.166*** (0.060)	-0.146*** (0.055)
<i>Board Size</i>	-0.002 (0.018)	-0.036 (0.025)	-0.024 (0.023)
Year FE	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes
Observations	4,697	4,463	4,445
R ²	0.590	0.592	0.490
Adjusted R ²	0.585	0.586	0.483
F Statistic	117.074**	111.902***	73.857***

Note: This table reports the results of the OLS regression of the model expressed in equation (2.1) describing the relation between advisory and innovation. *Patent_{t+1}* computes the log of the number of patents applied by a firm. *Cites_{t+1}* is the log of the number of citations received by the firm's patents. *Cites weight_{t+1}* is the log of the number of citations divided by the total number of citations in the same technology class and year. *Industry Expertise* is the total number of years the directors of the board worked in the same industry of the firm. *Support Specialist* is the ratio of directors having an experience in finance, law or public relation firms. *Community Influential* computes the ratio of directors with experience in government or public institutions. *Network* is the log of one plus the number of connections that directors have. *Firm size* is the log of total assets. *R&D* is the log of R&D expenses. *ROA* is the ratio between net income and total assets. *Leverage* is measured as the ratio between long term debt and shareholder equity. *Board Size* is the number of directors sitting at the board. Significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

4.2. The role of boards in promoting explorative and exploitative innovations

Now that we have demonstrated the existence of a relationship between a board's advisory capability and corporate innovation, we can now narrow our analysis to the types of innovation that boards can influence. More precisely, we will try to identify whether directors' experience and networks have an impact on exploratory or rather exploitative innovation activities. Exploitative innovations relate to projects that are close to the firm's area of current knowledge and commonly refers to incremental innovations. On the contrary, explorative innovation is created in areas less common to the firm and is typically associated with radical innovations (Christensen, 1997). Because of such characteristics, explorative innovations are considered riskier than exploitative innovations.

We identified explorative and exploitative innovation through seven variables and ran our regressions separately. Below, we define the models used in this section.

The first two models count the number of patents applied in technology classes that were either unknown or known to the firm. We define unknown patent classes as those in which a firm has not previously applied for any patent. On the contrary, classes in which a company has applied for patents are defined as known classes. We suppose that patents applied in unknown classes are related to more novel and exploratory innovations.

The second set of measures relates to models 3 to 6 and were computed following the methodology of Balsmeier *et al.* (2017). These dependent variables categorize the patents according to the number of citations they received relative to other patents in the same technology class at the same year. The four estimated models are exclusive and compute the dependent variable as following: the number of patents in the first percentile of citation distribution (*Top 1*); the number of patents that fall between the second and the tenth percentile of the citation distribution (*Top 10*), the number of patents below the tenth percentile but received at least one citation (*Below*) and the number of patents that have no citations (*No cites*). Such regressions aim to separate the effect on high- and low-quality innovation as well as failed innovations. We consider that highly cited patents are of great value and promote radical innovation (i.e. explorative innovation).

Model 7 uses the dependence variable self-citations. This variable computes the number of citations that a patent receives from patents belonging to the same company. An increase in self-citation indicates research in known areas of expertise while fewer self-citations show a broadening of innovation effort.

For each model and similarly to the baseline results, we transformed the dependent variable into a logarithm and lagged their value by one year. Table 2.3 summarizes the results obtained.

Table 2.3: Board's influence on explorative and exploitative innovations

	<i>Unknown</i>	<i>Known</i>	<i>Top 1</i>	<i>Top 10</i>	<i>Below Top 10</i>	<i>No cites</i>	<i>Self cites</i>
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>Industry Expertise_outsider</i>	-0.001** (0.0005)	0.001 (0.001)	0.0002 (0.001)	0.001 (0.001)	0.0005 (0.001)	0.001 (0.001)	0.005*** (0.002)
<i>Industry Expertise_insider</i>	0.0004 (0.001)	0.003** (0.001)	0.002** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.001 (0.002)	0.005* (0.002)
<i>Support Specialist_outsider</i>	-0.000 (0.001)	-0.000 (0.002)	0.000 (0.001)	-0.000 (0.002)	-0.002 (0.002)	0.001 (0.002)	-0.002 (0.004)
<i>Support Specialist_insider</i>	-0.004** (0.002)	-0.008 (0.005)	-0.003 (0.002)	-0.006 (0.004)	-0.007 (0.005)	-0.011** (0.004)	-0.008 (0.007)
<i>Community influentials_outsider</i>	-0.001 (0.001)	0.007** (0.003)	0.002 (0.001)	0.003 (0.002)	0.005** (0.002)	0.008*** (0.003)	0.005 (0.004)
<i>Community influentials_insider</i>	0.002 (0.003)	0.005 (0.005)	0.005** (0.002)	0.008* (0.004)	0.008* (0.005)	0.006 (0.005)	0.003 (0.007)
<i>Network_outsider</i>	0.000 (0.013)	0.052** (0.026)	0.019* (0.012)	0.054*** (0.020)	0.059** (0.023)	0.004 (0.026)	0.098** (0.043)
<i>Network_insider</i>	0.002 (0.008)	0.032* (0.018)	0.002 (0.009)	0.025* (0.014)	0.025 (0.016)	0.039** (0.016)	0.058* (0.033)
<i>Firm Size</i>	0.044*** (0.014)	0.124*** (0.037)	0.053*** (0.018)	0.099*** (0.027)	0.118*** (0.032)	0.136*** (0.032)	0.160*** (0.058)
<i>R&D</i>	0.065*** (0.015)	0.469*** (0.035)	0.108*** (0.016)	0.294*** (0.027)	0.366*** (0.030)	0.378*** (0.030)	0.405*** (0.051)
<i>ROA</i>	-0.013 (0.050)	-0.012 (0.085)	-0.062 (0.039)	-0.066 (0.060)	0.033 (0.075)	-0.025 (0.068)	-0.091 (0.136)
<i>Leverage</i>	-0.042* (0.023)	-0.119** (0.049)	-0.060** (0.025)	-0.137*** (0.037)	-0.122*** (0.045)	-0.090** (0.044)	-0.202*** (0.077)
<i>Board Size</i>	-0.004 (0.008)	-0.003 (0.019)	0.008 (0.011)	-0.017 (0.016)	-0.014 (0.018)	0.022 (0.017)	-0.031 (0.031)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,463	4,463	4,463	4,463	4,463	4,697	3,779
R ²	0.226	0.581	0.320	0.477	0.597	0.528	0.421
Adjusted R ²	0.216	0.576	0.312	0.471	0.592	0.523	0.412
F Statistic	22.5***	107.2***	36.4***	70.5***	114.5***	91.2***	48.326***

Note: This table reports the results of the OLS regression of the model expressed in equation (2.1) relating the type of innovation to board advisory capability. *Unknown* measures the number of patents applied in unknown technological classes. *Known* measures the number of patents applied in known technology classes. *Top 1* computes the number of patents that fall in the first percentile of the citation distribution. *Top 10* counts the number of patents that fall between the 2nd and 10th percentile of the citation distribution. *Below 10* computes the number of patents that fall in the under the 10th percentile of the citation distribution. *No cites* measures the number of patents that receive no citations. *Self-citation* computes the number of citations made by other patents of the same firm. Similarly to our baseline regression, all dependent variables have been lagged by one period. Advisory capability is measured with four variables and distinguished for insider and outsider. *Industry Expertise* is the total number of years the directors of the board worked in the same industry of the firm. *Support Specialist* is the ratio of directors with experience in finance, law or public relation firms. *Community Influential* computes the ratio of directors with experience in government or public institutions. *Network* is the total number of connections that directors have. Control variables are defined in the appendix. Significance levels: *p<0.1; **p<0.05; ***p<0.01

Relative to industry experience, insiders have a positive and significant coefficient on innovation similarly to our baseline results. This variable seems to promote exploitative innovation, as it is significant in models with patents applied in known classes (model 2) and patents situated in the middle and bottom of citation distribution (models 4, 5). We find a positive coefficient associated with patents in the first percentile of citation distribution (model 2), however its value is lower than in models 3 and 4 and less significant.

Relative to industry experience of outsiders we only find limited evidence that describes a negative impact on patents applied in unknown technological classes (model 1) and a positive impact of the number of self-citations (model 7). Such results indicate that industry expertise of outsiders is not useful in an innovation context.

Our expertise variable describes a concentration of knowledge and experience within the same industry as the operating firm. Such knowledge tends to bias directors to make decisions that are considered the norm in the industry. Consequently, out-of-the-box ideas and exploratory innovations seem harder to develop with an in-depth expertise. Our results are consistent with Haynes and Hillman (2010) which shows a negative relationship between the directors' expertise and strategic changes. This paper suggests that directors who are more embedded in a particular industry are less likely to consider alternative solutions to the industry norms.

Similar to our baseline results (Table 2.2), the *Support Specialists* variable is not significant for outsiders in any model. It has a significant negative coefficient for insiders on the number of patents applied in unknown technological classes (model 1) and the number of patents that did not receive citations (model 6). The presence of directors who secure external dependencies does not improve the innovation policy's outcome within the firm.

The *Community Influentials* variable seems to be associated with an increase in innovations unlike our baseline results. For outsiders, the variable is only significant in the models based on the number of patents applied in known technological classes (model 2) and patents situated at the bottom of citation distribution (models 5 and 6). For insiders, we observe positive and significant coefficients in the models based on the distribution of citations (models 3 to 5). More precisely, we find a positive and significant coefficient for the patent in the first percentile of the citation distribution (model 3). However, the value of the coefficient is lower than in models 4 and 5, suggesting a weaker effect on such innovations.

Similar to our baseline result, we find evidence that a director's network has an influence on innovation. The variable has a positive and significant coefficient for both types of directors

and in most of the models. *Network_outsiders* is positive and significant for every model except the *Unknown Class* models (column 1) and *No cites* (column 6). Evidence of insiders' networks is weaker as there are more models in which the variable has no statistical significance (models 1, 3 and 5) and coefficients have higher p-values.

When analyzing the innovation strategy of the firm, our results show that directors' networks have a greater influence on exploitative innovations than on explorative innovations. For both insiders and outsiders, the coefficient of the network variable is smaller in models of explorative innovation (e.g. models 1 and 3) than exploitative. Our network variable therefore promotes to a greater extent patents that are applied in known technological classes and that fall in the middle or bottom of the citation distribution. This suggests that directors' networks better reduce the uncertainty of less risky innovations.

Furthermore, when we compare the effect of both types of directors it appears that outsiders have a greater influence on innovation than insiders. The value of the *Network* variable estimated our models is systematically higher for outsiders than it is for insiders. In addition, outsiders have no influence on the number of patents that receive no citations or the number of self-citations. In contrast, insiders do have a positive and significant impact. Outsiders inherently have access to more information and opportunities as they sit on more boards than insiders. Consequently, this better connectedness allows them to effectively reduce uncertainties and enhance corporate innovation.

Such results on outsiders are similar to the finding of Balsmeier *et al.* (2017). In their paper, the authors argue that greater board independence increases exploitative innovation due to monitoring pressures. Because of greater monitoring, managers of the firm are focused on producing quantifiable results, which implies a reliance on safer innovations. Our findings suggest a similar interpretation but with a different variable.

Our results also add to the findings of Faleye *et al.* (2014). According to the authors, better-connected CEOs (and insiders) innovate more due to the presence of a labor market insurance, which is induced by the director's network. However, the limited results in models focusing on explorative innovation tends to invalidate such an interpretation. Indeed, following this interpretation, CEOs and insiders would take greater risk when innovating because they face less unemployment risk in the case of failure. Thus, insiders promote explorative innovation, which is riskier than exploitative innovations. The presence of labor market insurance does not seem to hold with our analysis. Our first interpretation of the network's role in reducing

uncertainties related to the innovative projects that may be exploitative is still valid however, as both insiders and outsiders positively influence exploitative innovations.

When summarizing the results obtained in this section we are able to say that a board's advisory capabilities have a limited impact on explorative innovations. Both types of directors promote exploitative innovation to a greater extent. In addition, we find little evidence that outsiders are better at promoting innovation than insiders. The network variable has a higher coefficient for outsiders than insiders. However, the latter sees a positive influence of their industrial expertise, which is absent for outsiders. Overall, our results do not validate our second hypothesis stating that independent director advising is better suited to enhance radical innovations.

4.3. Potential mechanism of influence: advising demand and high agency cost

In this section, we look at the effect of directors' resources and experiences on different types of firms in order to identify several mechanisms by which our baseline results occur. More precisely, we study firms based on their monitoring and advisory needs. For such firms, we expect to see a strong influence of the board's advisory capability.

In order to identify the monitoring and advisory needs of the firm, we use three criteria based on the size of the firm, the leverage ratio and the R&D intensity of the firm. For each criteria we run our baseline regression model for the firms that are above and below the median value of the criteria and compare our results. Our analysis enables us to compare the influence of the board's advisory capability in large vs. small firms, highly leveraged vs. lowly leveraged firms, and R&D intensive vs. non-R&D intensive firms.

According to Lu and Wang (2018), large and highly indebted firms lack incentives to innovate due to risk adversity. Coles *et al.* (2012) find that the need for advising increases with firm complexity (i.e. large and indebted firms). Lastly, innovative firms (i.e. firms with high R&D intensity) require more advising as they seek to develop several innovations. Additionally, R&D intensive firms face high uncertainty due to specific knowledge and investment of innovative projects. Consequently, they are more prone to agency issues.

Tables 2.4 to 2.6 present the impact of both independent and insider directors' advisory capability on firms' innovation when they are included in subsamples based on their size, leverage ratio, and R&D expenses.

Table 2.4 summarizes the results obtained when we analyze the subsamples based on the firm's size. Firms are considered large (resp. small) when the value of their assets is superior (resp. inferior) to the median value of total assets over the whole sample. The regressions show that experience variables have little impact on innovation from either type of director.

Similar to previous results, the *Industry Expertise* is only significant for the insiders and has no economic impact, as the values of the coefficients are small. *Support Specialists* variable is not significant for outsiders. As for insiders, it is significant and negative in the large firm sample. The *Community influentials* variable is only significant for outsiders. It is associated with a negative coefficient in the small firm sample (models 5 and 6) and a positive coefficient in one model of large firm sample.

The *Network* variable of independent directors show strong and interpretable results. One can observe that the coefficients are significant in both subsamples. Coefficients are higher in the small firm sample however. For insider directors, we find almost the opposite result: the only significant coefficient is found in the large firm sample, for the number of patents (model 1).

We still have results consistent with baseline: independent director's influence innovation outcome through their network while insiders through their expertise.

Our interpretation is that small firms may be less connected to their external environment than bigger firms. Consequently, the role of independent directors stands out more than in large firms. Moreover, one could argue that small firms are more dependent on external factors than large firms as they do not have as many resources or economic impact. Again, small firms rely more on outsiders for mitigating uncertainties.

Table 2.4: Board's impact on innovation in large and small firms

	Large firms			Small firms		
	<i>Patents_{t+1}</i>	<i>Cites_{t+1}</i>	<i>Cites weight_{t+1}</i>	<i>Patents_{t+1}</i>	<i>Cites_{t+1}</i>	<i>Cites weight_{t+1}</i>
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Industry Expertise_outsider</i>	0.002 (0.001)	0.002 (0.002)	0.002 (0.002)	-0.001 (0.001)	-0.001 (0.002)	-0.001 (0.002)
<i>Industry Expertise_insider</i>	-0.000 (0.002)	0.003* (0.002)	0.003* (0.002)	0.004 (0.002)	0.005 (0.003)	0.006* (0.003)
<i>Support Specialist_outsider</i>	-0.003 (0.003)	-0.003 (0.003)	-0.003 (0.003)	0.000 (0.002)	-0.001 (0.004)	-0.000 (0.003)
<i>Support Specialist_insider</i>	-0.016*** (0.006)	-0.016* (0.008)	-0.013* (0.007)	0.001 (0.005)	-0.009 (0.008)	-0.004 (0.007)
<i>Community influentials_outsider</i>	0.008** (0.004)	0.004 (0.004)	0.004 (0.004)	-0.003 (0.002)	-0.008** (0.004)	-0.007** (0.004)
<i>Community influentials_insider</i>	0.007 (0.008)	0.007 (0.009)	0.006 (0.008)	-0.001 (0.004)	-0.005 (0.007)	-0.002 (0.007)
<i>Network_outsider</i>	0.061* (0.037)	0.125*** (0.047)	0.125*** (0.044)	0.048* (0.028)	0.168*** (0.049)	0.143*** (0.044)
<i>Network_insider</i>	0.074*** (0.025)	0.038 (0.034)	0.044 (0.031)	-0.001 (0.017)	0.003 (0.029)	0.009 (0.026)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,915	2,802	2,791	1,782	1,661	1,654
R ²	0.590	0.615	0.515	0.256	0.368	0.178
Adjusted R ²	0.582	0.608	0.505	0.236	0.351	0.155
F Statistic	76.2***	81.4***	53.8***	13.0***	20.9***	7.8***

Note: This table reports the results of the OLS regression of the model expressed in equation (2.1) relating innovation to board advisory capability for different types of firms. *Patent_{t+1}* computes the log of the number of patents applied by a firm. *Cites_{t+1}* is the log of the number of citations received by the firm's patents. *Cites weight_{t+1}* is the log of the number of citations weighted by the total number of citations in the same technology class and year. Advisory capability is measured with four variables and distinguished for insider and outsider. *Industry Expertise* is the total number of years the directors of the board worked in the same industry of the firm. *Support Specialist* is the ratio of directors with experience in finance, law or public relation firms. *Community Influential* computes the ratio of directors with experience in government or public institutions. *Network* is the total number of connections that directors have. All controls are included in the regression but are not shown in the results. Control variables are defined in the appendix. Significance levels: *p<0.1; **p<0.05; ***p<0.01

Table 2.5 describes the results obtained for the subsamples of highly and lowly indebted firms. Firms are considered highly indebted (resp. lowly indebted) when the value of their assets is superior (resp. inferior) to the median value of total assets over the whole sample. Leveraged firms have a greater dependency to external resources and increase the conservatism of managers, which could prevent them from innovating. As a consequence, directors may have a role in shaping the innovation policy in such firms by monitoring managers.

Similar to our results based on the size of the firm, *Industry expertise_outsiders* has no significant impact on corporate innovation but *Industry expertise_insiders* does.

Again, there is no support that *Support Specialist_outsiders* has an impact on innovation. Only insiders have an influence, which is negative in highly indebted firms. *Community influentials_outsiders* promote innovation among indebted firms, while their influence is negative in lowly indebted firms. *Community influentials_insiders* does not show any significant result.

Outsiders' networks have a positive and significant coefficient in every model except the models based on patents for both subsamples. This suggests that they do not have different behavior for highly or lowly indebted firms. However, the coefficients are higher for the lowly indebted sample (models 4 to 6).

Our third hypothesis suggests that a director's advisory capability has a greater impact on innovation when firms are more dependent on their external environment (i.e. larger and more indebted firms). Our results do not suggest such an obvious relationship. We find mixed support for independent networks' influencing corporate innovation in firms that are more dependent on their environment. Insiders have an impact on larger firms and more indebted firms, but also on less indebted firms. *H3* finds therefore partial support.

Table 2.5: Board's impact on innovation in highly and lowly leveraged firms

	High Leverage			Low Leverage		
	<i>Patents_{t+1}</i>	<i>Cites_{t+1}</i>	<i>Cites weight_{t+1}</i>	<i>Patents_{t+1}</i>	<i>Cites_{t+1}</i>	<i>Cites weight_{t+1}</i>
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Industry Expertise_outsider</i>	0.001 (0.001)	0.002 (0.002)	0.002 (0.002)	0.001 (0.002)	-0.002 (0.002)	-0.002 (0.002)
<i>Industry Expertise_insider</i>	0.001 (0.002)	0.004* (0.002)	0.003 (0.002)	0.001 (0.003)	0.005* (0.003)	0.006** (0.003)
<i>Support Specialist_outsider</i>	-0.002 (0.003)	-0.000 (0.004)	-0.001 (0.003)	0.001 (0.003)	-0.001 (0.004)	0.001 (0.004)
<i>Support Specialist_insider</i>	-0.013** (0.006)	-0.015* (0.008)	-0.012 (0.007)	-0.010 (0.007)	-0.011 (0.009)	-0.010 (0.008)
<i>Community influentials_outsider</i>	0.013*** (0.003)	0.009** (0.004)	0.009** (0.004)	-0.002 (0.003)	-0.008* (0.005)	-0.007 (0.004)
<i>Community influentials_insider</i>	0.000 (0.006)	-0.003 (0.009)	-0.005 (0.007)	0.007 (0.007)	0.009 (0.009)	0.010 (0.008)
<i>Network_outsider</i>	0.052 (0.039)	0.090* (0.052)	0.087* (0.046)	0.012 (0.031)	0.147*** (0.046)	0.126*** (0.043)
<i>Network_insider</i>	0.070*** (0.027)	0.024 (0.037)	0.029 (0.033)	0.034 (0.021)	0.027 (0.030)	0.035 (0.029)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,565	2,472	2,459	2,132	1,991	1,986
R ²	0.603	0.623	0.532	0.583	0.570	0.462
Adjusted R ²	0.595	0.615	0.521	0.573	0.560	0.448
F Statistic	73.5***	76.8***	52.5***	60.6***	53.7***	34.6***

Note: This table reports the results of the OLS regression of the model expressed in equation (2.1) relating innovation to board advisory capability for different types of firms. *Patent_{t+1}* computes the log of the number of patents applied by a firm. *Cites_{t+1}* is the log of the number of citations received by the firm's patents. *Cites weight_{t+1}* is the log of the number of citations weighted by the total number of citations in the same technology class and year. Advisory capability is measured with four variables and distinguished for insider and outsider. *Industry Expertise* is the total number of years the directors of the board worked in the same industry of the firm. *Support Specialist* is the ratio of directors with experience in finance, law or public relation firms. *Community Influential* computes the ratio of directors with experience in government or public institutions. *Network* is the total number of connections that directors have. All controls are included in the regression but not shown in the results. Control variables are defined in the appendix. Significance levels: *p<0.1; **p<0.05; ***p<0.01.

Finally, Table 2.6 compares firms that have a high and low research and development intensity, which is computed as the ratio between R&D expenses and the total assets of a firm. This measure describes how much a company spends in research and development compared to the book value of its assets. Consequently, this variable is a proxy for both the level of uncertainty the firm faces and the level of knowledge needed. Typically, R&D intensive firms will develop many R&D projects that require specific knowledge and investments, rising the exposure of the firm to uncertainty and advising needs. Consequently, directors may provide monitoring and advising that will improve the outcome of the firm's innovation policy. Firms are considered as innovative (*resp. non-innovative*) when the value of R&D intensity is higher (*resp. lower*) than the median over the whole sample.

As insiders know the firm better and are more able to manage R&D project costs, we expect them to have a significant impact on corporate innovation in R&D intensive firms. Our results are consistent with this expectation. The variable *Industry Expertise* is positive and significant and in the innovative firm sample only. Moreover, the value of the coefficients is much higher than in previous tables. Additionally, we find that the *Network* variable has a positive and significant coefficient but only in innovative firms sample. Such results are consistent with Faleye (2007) stating that R&D intensive firms face greater uncertainty and higher advising demand that board of directors can provide. Consequently, we are able to validate our final hypothesis (*H4*).

In addition to these results, we find a positive and significant effect of independent directors' networks in both innovative and non-innovative subsamples. Outsiders are able to bring information and reduce uncertainties even in non-innovative firms. This, again indicates their ability to connect the firm and have access to information and opportunities. This adds to the findings of Coles *et al.* (2008) who finds only an impact from independent directors in R&D intensive firms.

Table 2.6: Board's impact on innovation in highly and lowly R&D intensive firms

	High R&D intensity			Low R&D intensity		
	<i>Patents</i> _{t+1}	<i>Cites</i> _{t+1}	<i>Cites weight</i> _{t+1}	<i>Patents</i> _{t+1}	<i>Cites</i> _{t+1}	<i>Cites weight</i> _{t+1}
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Industry Expertise_outsider</i>	0.001 (0.002)	-0.0004 (0.002)	0.0003 (0.002)	0.001 (0.001)	0.001 (0.002)	0.001 (0.002)
<i>Industry Expertise_insider</i>	0.005** (0.002)	0.010*** (0.003)	0.008*** (0.003)	-0.0002 (0.002)	0.003 (0.002)	0.003 (0.002)
<i>Support Specialist_outsider</i>	0.0002 (0.003)	-0.004 (0.004)	-0.002 (0.003)	-0.002 (0.003)	-0.0002 (0.004)	-0.0001 (0.003)
<i>Support Specialist_insider</i>	-0.017** (0.007)	-0.024** (0.010)	-0.021** (0.009)	-0.006 (0.006)	-0.004 (0.008)	-0.002 (0.007)
<i>Community influentials_outsider</i>	0.006* (0.003)	0.003 (0.004)	0.002 (0.004)	0.009** (0.004)	0.004 (0.005)	0.005 (0.004)
<i>Community influentials_insider</i>	0.008 (0.006)	0.009 (0.008)	0.009 (0.008)	0.001 (0.007)	-0.001 (0.009)	-0.001 (0.008)
<i>Network_outsider</i>	0.055 (0.041)	0.159*** (0.059)	0.136** (0.054)	0.016 (0.031)	0.090** (0.043)	0.088** (0.040)
<i>Network_insider</i>	0.051** (0.020)	0.064** (0.030)	0.069** (0.028)	0.041 (0.026)	-0.014 (0.035)	-0.002 (0.032)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,205	2,082	2,079	2,492	2,381	2,366
R ²	0.602	0.601	0.478	0.600	0.601	0.523
Adjusted R ²	0.595	0.593	0.468	0.591	0.591	0.512
F Statistic	86.2***	80.9***	49.2***	64.1***	61.5***	44.5***

Note: This table reports the results of the OLS regression of the model expressed in equation (2.1) relating innovation to board advisory capability for different types of firms. *Patent*_{t+1} computes the log of the number of patents applied by a firm. *Cites*_{t+1} is the log of the number of citations received by the firm's patents. *Cites weight*_{t+1} is the log of the number of citations weighted by the total number of citations in the same technology class and year. Advisory capability is measured with four variables and distinguished for insider and outsider. *Industry Expertise* is the average number of years the directors of the board worked in the same industry of the firm. *Support Specialist* is the ratio of directors with experience in finance, law or public relation firms. *Community Influential* computes the ratio of directors with experience in government or public institutions. *Network* is the average number of connections that directors have. All controls are included in the regression but not shown in the results. Control variables are defined in the appendix. Significance levels: *p<0.1; **p<0.05; ***p<0.01

5. Additional empirical work

5.1. Endogeneity in the board composition

Board composition is the result of an optimization of many elements dependent or not to the firm. Therefore, it is not exogenous to the firm but rather a choice made by the firm given certain characteristics and circumstances at the period of change (e.g. performance of the firm, strategic orientation, etc.). This could result in an over-estimated coefficient for our independent variable and generate misleading results. In the previous section of this chapter, we attempted to mitigate such issues by using several empirical techniques. First, we computed the innovation variable with a lag of one year. Second, we added industry and year fixed effects in our models, which control for potential endogeneity driven by a particular year or industry.

In this section, we chose to go further and realize an instrumental variable estimation of our model. We follow the work of Faleye *et al.* (2014) and use as an instrument the number of industries in which a director of the board previously worked. We believe this instrument is good for several reasons: it influences all of our main independent variables from the industry expertise to the number of connection directors have and it has no direct influence on innovation.

We run a Two-stage Least Square estimation in Table 2.7. As we have eight independent variables that we are interested in, we estimated eight models for the first stage of the methodology. This results in eight fitted variables that we use as independent variables in the second stage of the instrumental variable methodology.

We find consistent results for most of our variables of interest. Insiders' industry expertise is positive and significant. The variable of Community Influentials are positive and significant for both directors. The network of outsiders has a positive and significant coefficient in every estimated model.

However, we observe some modification and additional results compared to our baseline results. We see that the industry experience of outsiders has a negative and significant coefficient as does the Support specialist. Last, the network of insiders does not play a role and is no longer significant.

Table 2.7: Instrumental variable – second stage

	<i>Patents_{t+1}</i>	<i>Cites_{t+1}</i>	<i>Cites weight_{t+1}</i>
	(1)	(2)	(3)
<i>Industry Expertise_outsider</i>	-0.337** (0.136)	-0.454*** (0.165)	-0.426*** (0.149)
<i>Industry Expertise_insider</i>	0.528*** (0.074)	0.649*** (0.087)	0.603*** (0.079)
<i>Support Specialist_outsider</i>	-0.634*** (0.114)	-0.797*** (0.138)	-0.741*** (0.125)
<i>Support Specialist_insider</i>	1.804*** (0.440)	2.256*** (0.536)	2.146*** (0.486)
<i>Community influentials_outsider</i>	1.809*** (0.188)	2.147*** (0.205)	1.997*** (0.186)
<i>Community influentials_insider</i>	0.751*** (0.182)	0.994*** (0.226)	0.886*** (0.206)
<i>Network_outsider</i>	8.612*** (1.189)	10.381*** (1.129)	9.407*** (1.024)
<i>Network_insider</i>	-1.267 (3.468)	-0.364 (4.090)	0.003 (3.720)
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	4,445	4,445	4,445
R ²	0.595	0.584	0.482
Adjusted R ²	0.590	0.579	0.476

Note: This table reports the results of the second stage of the instrumental variables analysis conducted on the model expressed in equation (2.1) relating innovation to board advisory capability. *Patent_{t+1}* computes the log of the number of patents applied by a firm. *Cites_{t+1}* is the log of the number of citations received by the firm's patents. *Cites weight_{t+1}* is the log of the number of citations weighted by the total number of citations in the same technology class and year. Advisory capability is measured with four variables and distinguished for insider and outsider. *Industry Expertise* is the average number of years the directors of the board worked in the same industry of the firm. *Support Specialist* is the ratio of directors with experience in finance, law or public relation firms. *Community Influential* computes the ratio of directors with experience in government or public institutions. *Network* is the average number of connections that directors have. All independent variables are fitted from the first stage regressions of the analysis. All controls are included in the regression but not shown in the results. Control variables are defined in the appendix. Significance levels: *p<0.1; **p<0.05; ***p<0.01

5.2. Omitted variables

In this subsection we conduct two additional robustness tests. We run our baseline results and add two sets of omitted variables. The first set of variables is related to the characteristics of the board that could influence its composition, such as the educational background of the directors and the time spent in the position. Specifically, we add two variables that are the ratio of directors with a MBA on the board and the average number of years passed on the board. Our results are robust to such omitted variables.

The second set of variables relates to governance issues. We add two variables that take into account possible governance schemes that may affect corporate innovation: the total percentage of capital held by institutional investors and the antitakeover index (g-index) developed by Gompers *et al.* (2003). Again, we find consistent results with our baseline. Tables are in the appendix.

6. Conclusion

Our paper shed some light on a board's influence on corporate innovation. Our first finding was the demonstration of a positive relationship between advising and innovation. More precisely, we found that corporate innovation is mostly impacted by a director's network. Director's expertise in the industry or previous experience in the support sectors (finance, law and public relation firms) or public institutions have an influence of corporate innovation but it is smaller than the network. Directors' networks enable them to have access to valuable information that could be exploited by a firm's managers in order to reduce uncertainties related to innovative projects (Faleye *et al.*, 2014). On its side, industrial expertise enables them to gather specific knowledge about the firm and its sector. Overall, this work demonstrates that the resources dependence theory can be relevant when analyzing determinants of corporate innovation.

By distinguishing between outsider and insider directors, we were able to show that both types of director can enhance innovation in a firm. Insiders generally influence corporate innovation through their past experience, while outsiders have an impact through the use of their network. This is consistent with the idea that outsiders gather information outside the firm by sitting at multiple boards. On the contrary, insiders sit at fewer boards but stay longer in a specific industry, enabling them to gather information on a specific sector.

In the case of explorative innovations, we find little evidence of the influence of board advisory capability. We do not see a positive coefficient from a director's network or past experience in models of explorative innovation for both types of directors. Results about independent directors' networks are consistent with the finding of Balsmeier *et al.* (2017) and is related to their increased monitoring that prevents managers from taking risks. Findings related to insiders are also consistent with Haynes and Hillman (2010), which explains that such directors tend to focus on decisions that are the norm in their industry and do not consider alternative solutions.

We find evidence that the advising need of a firm increases the influence of the directors on innovation. We observe that insiders increase corporate innovation through their expertise in industry for large and R&D intensive firms. We do not find any effect of insiders' advisory capability in small and non-R&D intensive firms. However, relative to the subsamples based on the leverage ratio, our results are less clear.

Relative to outsiders, we do not observe that their influence is concerned by the level of advising needed. We find evidence that they improve corporate innovation in firms independently from their size, leverage ratio or R&D intensity. Our interpretation is that independent directors are particularly valuable for companies that have little access to opportunities and information on innovation. This adds to the findings of Coles *et al.* (2012), who suggest that large and highly indebted firms require more advice and therefore would rely more on directors' advising to innovate.

Further research on this topic could focus on the different types of connections directors can have. An interesting supplement to this paper could be looking at the influence of professional connections compared to education and personal connections. Further work could be done in analyzing the input of corporate innovation, namely R&D expenses, and how they are affected by board advisory capability.

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Appendices

Table 2.8: Definition of the variables

Variable	Definition	Source
<i>Patents</i>	Number of patents applied by the firm in a year	KPSS
<i>Citations</i>	Number of citations received by all the patents belonging to the firm in one year	KPSS
<i>Citations weighted</i>	The number of citations a patent received by other patents divided by the number of citation counts of other patents by other firms granted in the same year, in the same technology class	KPSS
<i>Industry Expertise_outsider</i>	Number of years the outsider director has been working in the same industry of the firm at which he sits	BoardEx
<i>Industry Expertise_insider</i>	Number of years the insider director has been working in the same industry of the firm at which he sits	BoardEx
<i>Support Specialist_outsider</i>	Ratio of outsider directors having previous experience in finance, law or public relation sectors	BoardEx
<i>Support Specialist_insider</i>	Ratio of insider directors having previous experience in finance, law or public relation sectors	BoardEx
<i>Community influentials_outsider</i>	Ratio of outsider directors having previous experience in the following sectors: Government, universities or charities	BoardEx
<i>Community influentials_insider</i>	Ratio of insider directors having previous experience in the following sectors: Government, universities or charities	BoardEx
<i>Network_outsider</i>	Number of overlaps the outsider directors have with other directors and senior executives	BoardEx
<i>Network_insider</i>	Number of overlaps the insider directors have with other directors and senior executives	BoardEx
<i>Firm size</i>	Log of total assets	Compustat
<i>ROA</i>	Ratio between the net income and shareholder equity	Compustat
<i>Leverage</i>	Ratio between Total Long Term Debt and Shareholder equity	Compustat
<i>R&D expenses</i>	Log of Research and Development expenses	Compustat
<i>Board Size</i>	Number of directors sitting at the board	BoardEx

Table 2.9: Pearson correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 <i>Patents</i>	1.000															
2 <i>Citations</i>	0.805	1.000														
3 <i>Citations weighted</i>	0.980	0.834	1.000													
4 <i>Industry Expertise_outsider</i>	0.118	0.050	0.116	1.000												
5 <i>Industry Expertise_insider</i>	0.107	0.113	0.113	0.114	1.000											
6 <i>Support Specialist_outsider</i>	0.082	0.010	0.069	0.183	(0.074)	1.000										
7 <i>Support Specialist_insider</i>	0.059	0.085	0.056	(0.076)	0.207	0.217	1.000									
8 <i>Community influentials_outsider</i>	0.173	0.082	0.160	0.240	0.043	0.255	0.011	1.000								
9 <i>Community influentials_insider</i>	0.087	0.114	0.093	(0.040)	0.176	(0.040)	0.151	0.047	1.000							
10 <i>Network_outsider</i>	0.286	0.139	0.275	0.424	0.040	0.455	0.051	0.349	(0.015)	1.000						
11 <i>Network_insider</i>	0.327	0.312	0.333	0.048	0.288	0.150	0.415	0.127	0.189	0.392	1.000					
12 <i>Firm size</i>	0.295	0.207	0.293	0.326	0.242	0.431	0.289	0.324	0.043	0.622	0.453	1.000				
13 <i>ROA</i>	0.050	0.034	0.049	0.121	0.117	0.081	0.020	0.060	(0.055)	0.136	0.044	0.331	1.000			
14 <i>Leverage</i>	0.018	0.005	0.009	0.108	0.083	0.195	0.173	0.092	(0.001)	0.173	0.136	0.358	0.075	1.000		
15 <i>R&D expenses</i>	0.393	0.287	0.399	0.332	0.152	0.310	0.151	0.350	0.114	0.618	0.456	0.783	0.128	0.143	1.000	
16 <i>Board Size</i>	0.185	0.120	0.174	0.422	0.366	0.316	0.267	0.290	0.087	0.586	0.467	0.672	0.156	0.289	0.482	1.000

Table 2.10: Spearman correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 <i>Patents</i>	1.000															
2 <i>Citations</i>	0.818	1.000														
3 <i>Citations weighted</i>	0.867	0.934	1.000													
4 <i>Industry Expertise_outsider</i>	0.220	0.068	0.170	1.000												
5 <i>Industry Expertise_insider</i>	0.128	0.136	0.111	0.133	1.000											
6 <i>Support Specialist_outsider</i>	0.107	0.062	0.109	0.198	(0.099)	1.000										
7 <i>Support Specialist_insider</i>	0.072	0.108	0.061	(0.028)	0.206	0.185	1.000									
8 <i>Community influentials_outsider</i>	0.202	0.105	0.155	0.250	0.037	0.236	0.058	1.000								
9 <i>Community influentials_insider</i>	0.077	0.087	0.063	(0.001)	0.207	(0.018)	0.166	0.061	1.000							
10 <i>Network_outsider</i>	0.347	0.211	0.326	0.445	(0.019)	0.427	0.087	0.319	0.024	1.000						
11 <i>Network_insider</i>	0.310	0.288	0.288	0.092	0.268	0.171	0.377	0.134	0.212	0.368	1.000					
12 <i>Firm size</i>	0.451	0.367	0.399	0.343	0.216	0.382	0.317	0.306	0.077	0.553	0.442	1.000				
13 <i>ROA</i>	0.162	0.127	0.149	0.156	0.148	0.081	0.045	0.086	(0.061)	0.163	0.039	0.346	1.000			
14 <i>Leverage</i>	0.111	0.075	0.073	0.197	0.135	0.223	0.214	0.137	0.051	0.232	0.165	0.504	0.012	1.000		
15 <i>R&D expenses</i>	0.651	0.505	0.578	0.335	0.146	0.287	0.187	0.310	0.137	0.566	0.472	0.770	0.160	0.256	1.000	
16 <i>Board Size</i>	0.261	0.172	0.211	0.428	0.284	0.293	0.305	0.292	0.152	0.546	0.436	0.643	0.179	0.429	0.451	1.000

Table 2.11: Omitted variables - Board characteristics

	<i>Patents_{t+1}</i>	<i>Cites_{t+1}</i>	<i>Cites weight_{t+1}</i>
	(1)	(2)	(3)
<i>Industry Expertise_outsider</i>	0.001 (0.001)	0.0005 (0.002)	0.001 (0.002)
<i>Industry Expertise_insider</i>	0.001 (0.002)	0.005** (0.002)	0.005*** (0.002)
<i>Support Specialist_outsider</i>	-0.001 (0.002)	-0.001 (0.003)	-0.001 (0.002)
<i>Support Specialist_insider</i>	-0.010** (0.005)	-0.012* (0.006)	-0.010* (0.006)
<i>Community influentials_outsider</i>	0.006** (0.003)	0.002 (0.003)	0.002 (0.003)
<i>Community influentials_insider</i>	0.004 (0.005)	0.003 (0.006)	0.003 (0.006)
<i>Network_outsider</i>	0.039 (0.026)	0.125*** (0.036)	0.112*** (0.033)
<i>Network_insider</i>	0.048*** (0.017)	0.023 (0.024)	0.029 (0.022)
<i>Firm Size</i>	0.149*** (0.034)	0.125*** (0.047)	0.125*** (0.042)
<i>R&D</i>	0.422*** (0.032)	0.493*** (0.043)	0.462*** (0.040)
<i>ROA</i>	0.016 (0.074)	0.066 (0.113)	0.002 (0.101)
<i>Leverage</i>	-0.119*** (0.045)	-0.164*** (0.060)	-0.145*** (0.055)
<i>Board Size</i>	-0.001 (0.018)	-0.038 (0.025)	-0.026 (0.023)
<i>MBA ratio</i>	-0.123 (0.141)	-0.237 (0.201)	-0.187 (0.185)
<i>Time in board</i>	0.003 (0.010)	-0.002 (0.014)	-0.003 (0.012)
Year FE	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes
Observations	4,697	4,463	4,445
R ²	0.590	0.592	0.490
Adjusted R ²	0.585	0.586	0.483
F Statistic	113.167***	108.218***	71.416***

Note: This table reports the results of the OLS regression of the model expressed in equation (2.1) describing the relation between advisory and innovation. *Patent_{t+1}* computes the log of the number of patents applied by a firm. *Cites_{t+1}* is the log of the number of citations received by the firm's patents. *Cites weight_{t+1}* is the log of the number of citations divided by the total number of citations in the same technology class and year. *Industry Expertise* is the total number of years the directors of the board worked in the same industry of the firm. *Support Specialist* is the ratio of directors having an experience in finance, law or public relation firms. *Community Influential* computes the ratio of directors with experience in government or public institutions. *Network* is the log of one plus the number of connections that directors have. Controls variables are defined in the appendix. *MBA ratio* is the ratio of board members with a MBA degree. *Time in board* is the average of number of years spend at the board of the firm. Significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 2.12: Omitted variables - Governance metrics

	<i>Patents_{t+1}</i>	<i>Cites_{t+1}</i>	<i>Cites weight_{t+1}</i>
	(1)	(2)	(3)
<i>Industry Expertise_outsider</i>	0.002 (0.002)	0.001 (0.002)	0.001 (0.002)
<i>Industry Expertise_insider</i>	0.003 (0.002)	0.006** (0.003)	0.006** (0.003)
<i>Support Specialist_outsider</i>	-0.003 (0.004)	-0.008* (0.004)	-0.008* (0.004)
<i>Support Specialist_insider</i>	-0.018 (0.011)	-0.021 (0.013)	-0.018 (0.014)
<i>Community influentials_outsider</i>	-0.0001 (0.004)	-0.002 (0.005)	-0.002 (0.005)
<i>Community influentials_insider</i>	0.001 (0.013)	-0.001 (0.017)	-0.0003 (0.017)
<i>Network_outsider</i>	0.133* (0.073)	0.231*** (0.088)	0.241*** (0.088)
<i>Network_insider</i>	0.030 (0.036)	0.002 (0.045)	0.012 (0.045)
<i>Firm Size</i>	0.292*** (0.076)	0.389*** (0.089)	0.380*** (0.088)
<i>R&D</i>	0.442*** (0.059)	0.415*** (0.072)	0.417*** (0.074)
<i>ROA</i>	0.403 (0.406)	-0.141 (0.630)	-0.258 (0.640)
<i>Leverage</i>	-0.045 (0.082)	-0.183* (0.107)	-0.172 (0.112)
<i>Board Size</i>	-0.056 (0.037)	-0.115*** (0.044)	-0.102** (0.044)
<i>Instit.</i>	-0.006* (0.003)	-0.005 (0.003)	-0.004 (0.003)
<i>G-index</i>	-0.026 (0.022)	-0.027 (0.027)	-0.023 (0.026)
Year FE	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes
Observations	637	619	615
R ²	0.641	0.588	0.556
Adjusted R ²	0.613	0.556	0.52
F Statistic	22.888***	18.190***	15.847***

Note: This table reports the results of the OLS regression of the model expressed in equation (2.1) describing the relation between advisory and innovation. *Patent_{t+1}* computes the log of the number of patents applied by a firm. *Cites_{t+1}* is the log of the number of citations received by the firm's patents. *Cites weight_{t+1}* is the log of the number of citations divided by the total number of citations in the same technology class and year. *Industry Expertise* is the total number of years the directors of the board worked in the same industry of the firm. *Support Specialist* is the ratio of directors having an experience in finance, law or public relation firms. *Community Influential* computes the ratio of directors with experience in government or public institutions. *Network* is the log of one plus the number of connections that directors have. Controls variables are defined in the appendix. *Instit.* is the percentage of shares held by institutional investors. *G-Index* is the governance index as computed by Gompers *et al.* (2003). Significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Chapitre 3. Bonds and convertible debt as a solution to suboptimal investments in innovation: a study on public US firms

Abstract

This paper explores the influence of public debt and convertible debt on innovation policies in companies. Using a sample of US-listed firms in the period between 1975 and 2000, we found that the ratio of public debt has a positive impact on corporate innovation. This is due to greater flexibility and tolerance for failure compared to bank debt. However, we found this relationship to be decreasing as the level of public debt rises, suggesting that its effect weakens when a certain level of public debt is reached. Further we studied this relationship when firms face a debt overhang situation and when there is a shareholders-creditors conflict. In such situations shareholders and debtholders may have divergent objectives about risky investments that public and convertible debt could alleviate. We do not find a positive influence of public debt financing in such firms. However, we find evidence that convertible debt has a positive effect on the quality of innovations in the situation of stakeholder conflicts. Convertible debt allows the investors to enjoy the potential upside of value when innovation projects succeed. On the contrary, when the project fails, such investors are protected from expensive losses. This indicates that convertible debt can mitigate the divergence of interest between shareholders and debtholders to invest in innovation and reduce risk-shifting incentives.

1. Introduction

In the early work of Modigliani and Miller the value of the firm is indifferent to the structure of financing¹⁷. In absence of friction (tax, agency costs, etc.), all projects with a positive Net Present Value are financed and the choice of financial structure does not impact the nature of the investment. However, companies face unique problems when investing in innovative projects, including: uncertainty of output (both in the probability of obtaining the output as well as the form of it, as stated by Kerr and Nanda, 2015), extremely skewed returns (Scherer and Harhoff, 2000), important information asymmetries (Aghion and Tirole, 1994; Hart and Moore, 1990), and the creation of significant levels of intangible assets. Such friction makes the evaluation of innovative projects difficult for external financiers and may prevent them from investing.

The literature seems to agree on the ability of financial markets to overcome these financial constraints (Brown *et al.*, 2009; Hsu *et al.*, 2014; Nanda, 2014). They have two influences that can positively impact corporate innovation. First, financial markets provide capital to the companies that are most likely to generate new processes or products (Rajan and Zingales, 1998).

Second, financial markets play a role at the micro level and may influence the nature of corporate innovations by bringing together stakeholders with different objectives (Hall and Lerner, 2010). Depending on the financing structure and the type of stakeholders involved, financial markets are able to influence the nature of innovative projects the firm undertakes (Akcigit and Kerr, 2018). According to Zingales and Rajan (2003), financial markets amplify the production of public information allowing many different investors to analyze and give an opinion on the investment. In an innovation context, the corporation will be able to reach many investors and possibly convince them of the quality of their innovation. However, a contradictory theory is developed by Holmstrom (1989). The author states that public financing induces short-term pressure on management and prevents them from investing in R&D and long-term projects due to personal career concern.

This paper focuses on the role of the capital structure in influencing corporate innovation. Since the literature that demonstrates the role of equity and banks is relatively broad, we chose to

¹⁷ See Modigliani and Miller (1958)

analyze the type of debt used by the firms and study the role of both public (e.g. bonds) and convertible debt.

Our innovation measures are based on the number of patents applied by a firm as well as the number of citations those patents received from others. Therefore, we are able to measure the volume (i.e. patents) and the quality (i.e. citations) of innovation developed within the corporation.

Our research is closely related to the paper by Atanassov (2015) who provides insights on the role of public debt in corporate innovation. The author argues that arm's length financing (i.e. debt issued on the financial markets such as bonds) allows greater flexibility and tolerance for failure, which improve the firm's innovation output. Consequently, our research tries to go a step further by asking two research questions.

First, we identify if public debt is always used as a financing tool in an innovative company. More precisely, we investigate the shape of the relation between public debt and innovation as the level of public debt increases. We try to identify if there is a non-linear (e.g. concave) relation between the two variables. This analysis is motivated by the findings of Aghion *et al.* (2004), who demonstrate the existence of an inverted U-shape relationship between innovative activities and debt financing. Firms that significantly spend on R&D projects, relative to their assets, tend to use less bank financing. Our paper tries to identify the nature of the relationship between debt and innovation through the lens of public debt.

Second, we wish to study the influence of both bond and convertible debt on the firm's innovation policy when firms may face a sub-optimal investment situation. Respectively, we examine the situation of a debt overhang and creditor-shareholders conflict.

Firms face a debt overhang issue when they already bear a heavy burden of debt and they may not be able to raise additional debt to finance a good innovative project. Since the value of the debt is close to the book value of assets, debtholders may not recover the value of their claim and might prevent financing new investments, eventually leading to underinvestment. Similarly, shareholders do not issue new equity, since most of the payoffs of the project would be used to pay the interest of the existing debt. Additionally, from the company's point of view, managers of such firms tend to be more risk-averse. We use the debt to asset ratio to identify firms that may face a debt overhang situation.

We use the framework of Myers (1977) to examine the opposition in creditors' and shareholders' goals. Since shareholder's payoff can be assimilated to a call option, they might seek risky investments projects (and over invest in innovative activities). On the contrary, creditors would prevent from investing in such risk-projects (and under investment in innovation) because their pay-offs are capped to the value of their claim. Consequently, shareholders have incentives to implement risk-shifting mechanisms and take excessive risk by investing in projects that may have a negative Net Present Value. By doing so, shareholders may substitute value from creditors.

We use three criteria to depict situations where the value of the firm is stressed and might lead to shareholder-creditor conflicts: negative book value of equity, market-to-book ratio inferior to one and negative operational cash flow. Such firms, could see innovation as a way to improve their operations and would be keen to enhance corporate innovation by raising external funds (e.g. equity and debt). However, these firms cannot easily raise outside financing. We wonder if public and convertible debt are able to relieve financial constraints of such firms and promote corporate innovation by reducing shareholder-creditor conflicts.

Using a dataset of approximately 150,000 observations for 17,000 publicly traded US firms, we demonstrate the positive influence of public debt on corporate innovation. Supporting the view of Atanassov (2015), a greater amount of public debt allows the firm to produce more and higher-quality patents. We interpret these positive findings by the greater tolerance of bondholders and increased firm's attractiveness toward investors.

However, we show the presence of a non-linear relationship between public debt financing and corporate innovation, which is consistent with Aghion *et al.* (2004). As the use of public debt increases, its positive effect on corporate innovation diminishes. This illustrates a concave relation between the two variables. This would imply that companies investing heavily in innovation would not use public debt as a financing tool. Additionally, it suggests that public debt has a limited effect on the tolerance for risk.

We find that a greater level of convertible debt has a positive influence on citations but not the number of patents. The presence of a convertible option does not imply a greater number of innovation projects but rather a greater quality of innovative projects undertaken.

In order to study debt overhang situations, we created three samples containing corporations with a debt-to-asset ratio above the median, above the 75th percentile, and above the 90th percentile of the sample. Our results show that as the leverage ratio increases, the influence of

public debt diminishes. The variable is not significant in samples above the 75th and 90th percentile. In addition, we observe no significant coefficients for the convertible debt variable. This suggests that neither public debt nor convertible debt are good elements to promote innovation among firms facing debt overhang issues and under investment in innovation.

To examine situations in which firms may be facing stakeholder conflict situations, we created subsamples whenever companies had negative book value of equity, a market-to-book ratio below one or negative operational cash flow. Our results show little evidence of the influence of bondholders in such situations. When studying the influence over the number of patents, there is only one subsample in which the public debt variable has a positive and significant coefficient. Relative to the number of citations we find a negative influence of the variable in the negative book to equity subsample and a positive influence in the market to book inferior to one sample. Such findings do not enable us to make clear interpretations.

There is more evidence on the positive role of convertible bonds. We found a positive and significant coefficient in every subsamples constructed for the models with the number of citations as a dependent variable. When focusing on patents, we see no significant coefficient for the variable. Again, we find that convertible debt has no influence on the number of innovative projects undertaken but rather their quality.

Convertible bonds enable investors to protect themselves if the innovative projects fail. On the contrary, if the project succeeds, convertible bonds enable investors to enjoy the upside of the value created. Additionally, such an instrument is also able to reduce divergence of interest between shareholders and debtholders. The presence of convertible bonds reduces the shareholder's incentive to invest in numerous risky projects (i.e. no influence of the number of patents) yet increases the quality of patents (i.e. positive effect on patent citations). Consequently, the firm does not take more risk in volume by increasing the number of patents, but rather improves the quality and the value of the patent applied. This is evidence that the asset substitution incentives of the shareholder are reduced with convertible debt.

Our contributions to the literature are multiple. We have added to the body of research on the influence of financial structure on corporate innovation by demonstrating the presence of a non-linear relationship between public debt and innovation. Moreover, we have contributed additional insight on the role of convertible bonds in the extreme situations firms may face.

The paper proceeds as follows: Section 2 describes the related literature and develops our testable hypothesis; Section 3 details our variables, construction, and our empirical

methodology; Sections 4 and 5 describe the results obtained; and finally, Section 6 concludes the paper.

2. Literature review

There is consistent literature proving that equity financing positively influences innovation among corporations. According to Brown *et al.* (2009), R&D financing is made through internal funds or equity markets for young, high-tech, public firms. Moreover, Acharya and Xu (2017) demonstrate that public firms that depend more on external financing tend to create more, higher-quality patents than private firms do. The authors argue that equity capital markets are better at financing innovation than banks because innovation is beset with informational problems, uncertain returns, and lack of collateral. Banks, therefore, would be taking high risks in financing such projects.

Recent research shows mixed evidence concerning the role of banks in financing innovation. On the one hand, Hall and Lerner (2010) point out that banks are not able to play a role in innovative development due to high-risk adversity and short-term orientations, and do not benefit from the firm's innovation success and increased value. On the other hand, several papers argue that banks do have an important influence on corporate innovation. Nanda (2014) shows that the drop in credit financing caused by the 1929 crisis led to a decrease in innovation among firms. It also shifted the tone of innovation from the radical or explorative towards the modest and the incremental. Moreover, papers show that debt financing is relatively common for young and innovative companies and that patents are often used as collateral (Mann, 2018). In fact, Mann points out that firms which use their patents as collateral have performed more than 40% of the patenting since 2003. Robb and Robinson (2014) demonstrate that external bank financing is an important source of start-up capital, even for high-potential start-ups that might be engaged in innovation and which do not have any collateral—tangible or intangible—to pledge.

As the literature on the influence of debt is relatively extensive and offers many mixed conclusions, this relationship should be studied from a different angle. We chose to focus our analysis on the role of public and convertible debt. A greater proportion of such debt in the firm's balance sheet may influence corporate innovation differently than bank debt.

By nature, public debt reaches a crowd of investors who have different backgrounds and profiles. This diversity of investors enables them to better evaluate innovative projects than a single bank (Rajan and Zingales, 2003). Therefore, the firm can appeal to a wide range of potential investors and persuade at least some of them that the new technology will be successful. This vision of arm's-length financing is demonstrated by the work of Atanassov (2015): a greater proportion of public debt funding is positively related to the number of patent applications and citations. The reason, he argues, is it due to a greater flexibility and tolerance for failure from bondholders.

However, Aghion *et al.* (2004) suggest that innovative firms will rely on debt financing only up to a certain point. They demonstrated the existence of a non-linear relationship between the level of R&D intensity of the firm and its debt financing. Their findings suggest that as the firm increases its investment in R&D, the proportion of financing from banks decreases.

Such elements allow us to formulate our first hypothesis:

H1: There is a concave relationship between the level of public debt used by the firm and its innovation outcome.

We take a closer look at the influence of public and convertible debt on corporate innovation. We select two situations in which the typology of debt could play a significant role.

We first focus on highly leveraged firms that typically face a debt overhang problem. It prevents them from investing in good and valuable innovative projects since they already have a great level of debt and face an excessive charge of interest. Consequently, creditors of highly leveraged firms see a rise in the default risk of the firm and would avoid increasing the level of debt since it is close to the value of assets. Additionally, such firms are often characterized by a corresponding adversity to high risk from managers (Brisker and Wang, 2017; Hirshleifer and Thakor, 1992). Because public debt is a source of flexibility and has a greater tolerance for failure, it could imply a greater level of innovation even in highly leveraged firms. We present the following testable hypothesis:

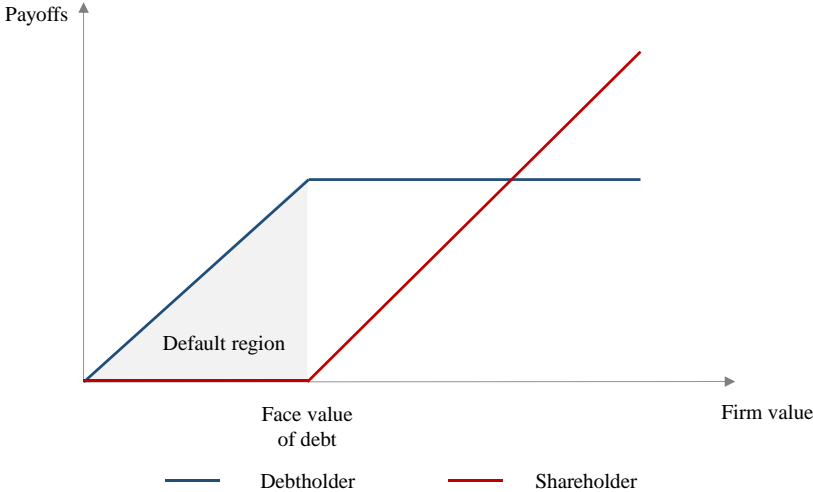
H2a: Public debt is able to mitigate the debt overhang issue and enhance investments in innovation.

H2b: Convertible debt is able to mitigate the debt overhang issue and enhance investments in innovation.

To test this hypothesis we studied the nature of the relationship between public debt and corporate innovation by splitting our samples into subsamples based on the leverage ratio of firms.

A firm faces a conflict between shareholders and creditors when the market value of its assets may not be sufficient to cover the value of its obligations toward debtholders. As shown in Figure 3.1, debtholders see their payoffs increase with the firm's value. However, the payoffs to these debtholders are capped by the value of their claim. As soon as the company's value falls below the value of its assets, debtholders see their payoffs decrease. For shareholders, it is quite the opposite: their payoffs are assimilated to a call option and have unlimited payoff as soon as the value of the firm exceeds the value of its assets; otherwise, the value of their claim is zero.

Figure 3.1: Payoffs to stakeholders



When a firm approaches the default region, debtholders and shareholders face contradictory goals because of the nature of their payoffs (Myers, 1977). Shareholders could gain from investing in risky projects, which would increase the value of the firm. If the investment fails and decreases firm value, they have little to lose since their payoffs are already close to zero. On the contrary, debtholders would avoid investing in risky projects because they do not benefit from any ensuing increases in the value of the firm; they only face a risk of decreased payoffs if the investment fails.

Since we do not have data related to defaulted and distressed firms we suppose that firms facing operational difficulty are candidates for shareholder-creditor conflicts.

Firms facing operational difficulties can find in innovations a way to find growth and improve their state of difficulty. However, they have difficulty raising external financing due to their situation. By issuing public debt and convertible debt the firm could alleviate such issues and find investors to finance their innovation opportunities.

Since bondholders appear to promote greater flexibility and tolerance to failure, one might expect that they would behave differently than a bank in such situations. In addition, such investors increase the attractiveness of the firm which could increase the number of investors that could finance innovative projects. However, bond investors remain debtholders and could behave in a way that would prevent the firm from investing in innovative development. This setting provides us with the following testable hypothesis:

H3a: For firms close to their default, the ratio of public debt is positively (resp. negatively) associated with corporate innovation.

A mitigating instrument of this relationship would be the convertible option present in some bonds that gives the debtholder the possibility to enjoy an increase in the company's value. Therefore, in the area of default such debtholders could behave like equity investors, incentivized to take risks and improve innovation in the firm.

H3b: Convertible bonds attenuate the friction between shareholders and debtholders near the default point and improve the level of investments in innovation.

3. Data and methodology

Our sample is composed of US-listed companies in the period between 1975 and 2000. The sample was constructed by merging several databases in order to compute variables related to debt, innovation, and accounting. Debt-related data was downloaded from SDC Platinum. Innovation data came from the NBER patent database. Lastly, we used Compustat for accounting and financial data relative to the firms.

3.1. Financing variables

Similarly to Atanassov (2015), we computed various measures surrounding the public financing of companies. The first variable measured the amount of public equity the firms had. *Public Equity* being defined as the ratio between the book value of equity and the total assets of the firm. Both book value and total asset inputs were extracted from Compustat.

From SDC Platinum, we extracted every bond issue by a US-listed company between 1975 and 2000 in order to compute the *Public Debt* variable. This variable is the ratio between the outstanding amount of bond debt and the total assets of the firm. The outstanding amount of the bond is equal to the proceeds obtained at the issue date, which we considered constant until the bond's maturity date. Then, we added up the outstanding amounts at the company level for each year of our sample.

We went a step further in the debt composition, identifying the amount of bonds that are convertible using Compustat. The variable represents all long-term debt (i.e. notes, bonds, debentures, and subordinated debt) convertible to the company's common or preferred stock. We computed the ratio between the outstanding amount of convertible bonds and the firm's total assets, which give us the *Convertible* variable.

3.2. Innovation variables

We used the NBER dataset, which gathers information on patents that have been granted to firms between 1975 and 2006. After that, we analyzed the measures of innovation that are traditional in the literature. First, for each year and for each firm we computed the number of patents granted (*Patents*). This variable measures the volume of innovation produced among the corporation.

However, the number of patents does not capture the dimension of success and quality of innovation. We therefore used the number of citations received by patents for our second set of measures. A high number of citations indicates that the patent is important to the economy, while lower-cited patents do not seem as relevant or influential.

Moreover, because the raw citation counts are subject to truncation bias due to the finite length of the sample, we adjusted the citation measure using the methodology of fixed-effects indicated by Hall *et al.* (2005, 2001). As the number of patent citations accumulates over the years, patents granted in the end of the sample have fewer years to accumulate them. Therefore, such patents are not comparable.

We made two adjustments over the course of our research to take into account time and technological class effects.

Cites Time_{t+1} is the number of citations adjusted by time effect. It is the ratio between the number of citations received by a firm in a year and the average number of citations received by all patents in the same year.

Cites Time Class_{t+1} is the number of citations adjusted by time and technological class effect. The variable is computed as the ratio between the number of citations received by patents in different classes for each firm in a year and the average number of citations of patent in each patent class in the same year. The formula for both adjusted variables is given in the appendix.

3.3. Controls

We analyzed several control variables that are commonly used in the field through Compustat. *R&D* is the log transformation of R&D expenses. *Sales* is the log transformation of the net sales. *Ret. earnings* is the ratio between retained earnings and total assets. *EBITDA* is the ratio of EBITDA on total assets. *Cash* is the ratio between cash and total assets. *Tangible* is the portion of tangible assets (property, plant and equipment items) among the firm's total assets. *HHI* is the Herfindahl index of the total sales computed using the four-digit SIC code from Compustat. *HHI_2* is the square of *HHI*. The leverage variable used to construct our subsamples is computed as the ratio between total debt and total assets.

To illustrate the situation of firms facing operational constraints we computed three subsamples using the book value of equity, market to book, and operational cash flow. These variables are calculated using data extracted from Compustat.

We computed the market-to-Book ratio as the ratio between market capitalization and the book value of equity. Market capitalization is calculated as the product of the share price and the outstanding number of shares at December 31 of each year.

3.4. Empirical methodology

As previously stated, our database is compiled from three different databases using distinct identifiers. Our first merge was made between the NBER and Compustat databases using the identifier of the Compustat database (*gvkey*). This was accomplished by linking the patent data, which uses the *pdpass* as identifier, to the *gvkey* using a link table provided by the NBER. Following Atanassov, (2015) in addition to the merged firms, we integrated every company within Compustat that belongs to the same four-digit SIC code of merged companies. This is meant to reduce the selection bias because our sample construction is independent of whether firms have patents or not.

Merging the SDC dataset with the previous data was done in several steps. As SDC uses the historical CUSIP (NCUSIP) and Compustat (the current CUSIP), we also used a link table. This table was extracted from CRPS, which has traced every CUSIP for each company in the base since its creation. Consequently, we were able to associate the NCUSIP present in SDC to the current CUSIP of the firm.

The CUSIP identifier in the link and the SDC database, however, do not have the same length (8 and 9, respectively) so we trimmed the length of the CUSIP present in SDC to six digit CUSIP and then added “10” at the end, giving us an eight-digit CUSIP.

Our final database is composed of approximately 150,000 observations for 17,000 firms. However, we lost a significant amount of data due to missing R&D expenses.

In order to identify the influence of debt composition on corporate innovation, we ran regressions with Poisson models. The main model used in the paper is the following:

$$\begin{aligned}
 Innovation_{i,t+1} = & \exp(\beta_1 * Public\ equity_{i,t} + \beta_2 * Public\ debt_{i,t} \\
 & + Controls_{it} + \mu_k + \mu_t)
 \end{aligned}
 \tag{3.1}$$

Our models were run with both year- and industry-fixed effects (μ_t and μ_k , respectively). We used the three-digit SIC code for our industry-fixed effect. Standard errors were clustered at the firm level. Our variables are winsorized at the first and ninety-ninth percentile in order to delete the effect of outliers. We lagged the innovation variables by one year in order to take into account a degree of causality in our analysis. All innovation variables were computed from the patent's application date and rounded to the superior integer.

As our paper aims to study the nature of the relationship between public debt and innovation, we chose to create subsamples of firms that are highly leveraged and facing operational difficulties.

We evaluated a firm's leverage based on the debt-to-asset ratio. We constructed three subsamples for our analysis: firms above the median, the 75th percentile, and the 90th percentile of the ratio. Our motivation for looking at these firms was that the value of their debt is close to the value of their assets. As a consequence, debtholders would not recover their claim in the case of default. Moreover, such firms are notoriously risk-averse (Brisker and Wang, 2017; Hirshleifer and Thakor, 1992) and face a debt overhang problem. Therefore, the presence of bondholders and convertible debt could help the firm take greater risks and invest in innovation activities.

We identified firms facing operational difficulties according to three criteria: firms having negative book value of equity, market to book ratio inferior to one, and negative operational cash flow.

Negative book value of equity indicates that debts are superior to the value of the firm's assets and represents how many assets a company would have left if it were to go out of business today. One reason for negative book value is accumulated losses over the years. It reduces retained earnings and decreases equity value. Another reason is commonly due to a large dividend payment to the firm's shareholders, which also leads to a reduction of retained earnings. In the end, a negative book value of equity could be a sign that the firm faces operational difficulties or that it reinvested its cash outside the firm instead of increasing the level of investments which decrease value for the firm.

A market-to-book ratio less than one indicates that the market capitalization is inferior to the book value of equity. It is equivalent to say that the market value of firm (enterprise value) is

lower than the book value of assets¹⁸. Enterprise value can be seen as the sum to the infinite of the free cash flow of the firm. Therefore, if such a value is inferior to the book value of assets, it means that the firm is not able to generate value from its activity.

Finally, negative operational cash flow indicates that the firm does not generate value from its operational activities. It could imply that the firm does not have enough sales to cover its expenses or simply that it is not being paid by its client soon enough.

3.5. Descriptive statistics

Table 3.1: Descriptive statistics

Variables	Obs.	Mean	ST. Dev.	Skewness	Kurtosis	Min.	Median	Max.
<i>Patents</i>	153,577	5.489	56.472	27.775	1,180.515	-	-	4,344.000
<i>Citations_time</i>	144,494	2.875	13.419	6.458	43.919	-	-	107.986
<i>Citations_class</i>	144,494	3.013	13.971	6.409	43.258	-	-	111.926
<i>Public Equity</i>	153,335	0.421	0.463	(3.544)	17.965	(2.496)	0.481	0.972
<i>Public Debt</i>	153,380	0.010	0.047	5.279	28.414	-	-	0.321
<i>Leverage</i>	153,577	0.280	0.292	2.260	7.771	-	0.224	1.786
<i>Convertible debt</i>	150,751	0.016	0.059	4.642	22.598	-	-	0.387
<i>log(R&D)</i>	83,627	1.270	1.476	1.444	1.737	-	0.729	6.513
<i>log(sales)</i>	152,784	3.903	2.305	0.231	(0.569)	-	3.825	9.560
<i>Ret. earning/asset</i>	151,547	(0.576)	2.554	(5.235)	30.850	(18.825)	0.100	0.775
<i>EBITDA/asset</i>	152,053	0.018	0.362	(3.758)	17.293	(2.184)	0.108	0.441
<i>Cash/asset</i>	136,682	0.098	0.153	2.688	7.637	-	0.036	0.809
<i>Tangible</i>	153,119	0.310	0.234	0.863	(0.056)	-	0.255	0.930
<i>Market to Book</i>	125,303	2.648	4.892	3.592	19.303	(10.764)	1.488	33.450
<i>HHI</i>	153,577	0.237	0.168	1.449	2.084	0.045	0.194	0.839

The table above summarizes descriptive statistics for the sample used in this paper. Similarly to other publications, we have very skewed and volatile data relative to innovation. This is not surprising as our dataset comprises firms from Compustat that do not have any patenting activity. As a consequence we have numerous firms with innovation variables equal to zero. However, there are some firms that are great innovators as one can see with the maximum values for the three innovation variables.

¹⁸ Because, $\frac{\text{Market Cap.}}{\text{Book val. equity}} < 1$, we can write the following: $\text{Market Cap.} < \text{Book val. assets} - \text{Liabilities}$. Consequently, we have the following expression: $\text{Enterprise value} < \text{Assets}$

Relative to financing structure, only a limited number of firms use public debt financing. There are 1,390 firms in our sample that have used at least once over the sample's period. This explains that the mean is close to zero. It is similar for the Convertible debt variable. There are 4,500 firms using such financing tools.

4. Main empirical findings

4.1. Firms' capital structure and innovation

In this section, we present the baseline results of our paper. The two tables below describe the relationship between public debt, the number of patents (Table 3.2) and the adjusted number of citations received (Table 3.3). These tables also include results on the non-linear nature of the relationship of debt as well as the effect of convertible bonds.

We found results similar to the findings of Atanassov (2015). Our models show a positive relationship between the ratio of arm's-length financing and both the number of patents and adjusted number of citations. The magnitude of the effects is quite strong for both variables: in column 2 of the Table 3.2, an increase in one standard deviation of *Public Equity* (0.46) leads to an increase of 38.6% of patents from its mean value, all else being equal¹⁹. Similarly, an increase in one standard deviation of *Public Debt* (0.05) leads to an increase in 8.4% of patents from its mean value, all else being equal²⁰.

We discovered similar results when studying the relationship between debt composition and citations. For both adjusted variables of the number citations *Public Equity* and *Public Debt* are associated with a positive and significant coefficient. Our results demonstrated the presence of an economic magnitude. In model 2 of Table 3.3, an increase in one standard deviation of *Public Equity* (0.46) led to an increase of 48.2% of citations, all else being equal²¹. Similarly, an increase in one standard deviation of *Public Debt* (0.05) led to an increase in 8.4% of citations, all else being equal²².

¹⁹ $e^{0.707 \times 0.462} - 1 = 38.6\%$. This economic magnitude is rather large due to the high value of standard deviation of the public equity variable.

²⁰ $e^{1.709 \times 0.047} - 1 = 8.4\%$

²¹ $e^{0.852 \times 0.462} - 1 = 48.2\%$

²² $e^{1.715 \times 0.047} - 1 = 8.4\%$

Our results also indicated the presence of a non-linear relationship between debt and innovation. In the column 3 of Table 3.2, the coefficient associated with the square of *Public Equity* has a negative and significant coefficient. Such results are similar for citations, as shown in columns 3 and 7 of Table 3.3. This negative coefficient implies that as the public debt ratio increases the influence of the *Public Debt* variable diminishes. This is consistent with the findings of Aghion *et al.* (2004). These results support the first hypothesis of our paper.

We found contrasting results when introducing the Convertible variable in our regressions. The variable did not have a significant influence on the number of patents (Table 3.2, model 4). However, the variable did have a positive and significant impact on the adjusted number of citations. Respectively, in models 4 and 8 of Table 3.3, the variable was associated with a coefficient equal to 1.153 and 0.999. Such coefficients imply that the number of citations increased by 6.9% and 6% in the presence of convertible debt, all else being equal. It seems that the option to convert the debt plays a role only on the quality and not on the volume of innovation.

Table 3.2: Influence of public and convertible debt on the number of patents

	<i>Patent_{t+1}</i>			
	(1)	(2)	(3)	(4)
<i>Public equity</i>	0.581*** (0.136)	0.707*** (0.148)	0.655*** (0.145)	0.696*** (0.147)
<i>Public debt</i>		1.709*** (0.332)	4.693*** (0.950)	4.937*** (0.954)
<i>Public debt</i> ²			-14.068*** (3.543)	-15.606*** (3.643)
<i>Convertible</i>				0.622 (0.387)
<i>R&D</i>	0.608*** (0.034)	0.603*** (0.034)	0.602*** (0.034)	0.609*** (0.033)
<i>Sales</i>	0.254*** (0.031)	0.257*** (0.031)	0.246*** (0.030)	0.246*** (0.030)
<i>Ret. earnings</i>	0.013 (0.020)	0.003 (0.019)	0.004 (0.019)	0.001 (0.018)
<i>EBITDA</i>	-0.357*** (0.121)	-0.340*** (0.120)	-0.312*** (0.118)	-0.314*** (0.119)
<i>Cash</i>	0.072 (0.193)	0.142 (0.187)	0.195 (0.185)	0.175 (0.186)
<i>Tangible</i>	0.516*** (0.194)	0.487** (0.191)	0.448** (0.190)	0.400** (0.195)
<i>MtoB</i>	0.017*** (0.004)	0.017*** (0.004)	0.017*** (0.004)	0.017*** (0.004)
<i>HHI</i>	0.321 (0.590)	0.423 (0.584)	0.449 (0.585)	0.239 (0.569)
<i>HHI</i> ²	-0.626 (0.722)	-0.723 (0.723)	-0.754 (0.732)	-0.437 (0.696)
Year FE	Yes	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes	Yes
Observations	58,349	58,349	58,349	57,831
Log Likelihood	-198,895.600	-197,353.200	-196,520.300	-191,996.800
Akaike Inf. Crit.	398,283.100	395,200.400	393,536.600	384,491.600

Note: This table presents the results of the Poisson regression of the model presented in equation (3.3.1). *Patent_{t+1}* computes the round number of patents applied by a firm. *Public equity* is the ratio between shareholder equity and total assets. *Public debt* is the ratio between the outstanding amount of bonds and total assets. *Public debt*² is the square term of the *Public debt* variable. *Convertible* is the ratio between the book value of convertible debt and total assets. *R&D* is the log of 1+R&D expenses. *Sales* is the log of 1+Total sales. *Ret.earning* is the ratio between retained earnings and total assets. *EBITDA* is the ratio between EBITDA and total assets. *Cash* is the ratio between the amount of cash available and total assets. *Tangible* is the ratio between PPE and total assets. *MtoB* is the ratio between market capitalization and book value of equity. *HHI* is the Herfindahl index based on total sales and *HHI*² its square term. Significance levels: *p<0.1; **p<0.05; ***p<0.01

Table 3.3: Influence of public and convertible debt on the number of citations

	<i>Cites Time</i> $t+1$				<i>Cites Time Class</i> $t+1$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Public equity</i>	0.722*** (0.149)	0.852*** (0.162)	0.797*** (0.158)	0.869*** (0.161)	0.695*** (0.146)	0.825*** (0.159)	0.769*** (0.155)	0.831*** (0.157)
<i>Public debt</i>		1.715*** (0.369)	5.227*** (1.093)	5.615*** (1.106)		1.729*** (0.368)	5.234*** (1.066)	5.581*** (1.076)
<i>Public debt</i> ²			-16.470*** (4.025)	-19.431*** (4.179)			-16.455*** (3.901)	-18.994*** (4.028)
<i>Convertible</i>				1.153*** (0.400)				0.999** (0.400)
<i>R&D</i>	0.627*** (0.036)	0.621*** (0.035)	0.620*** (0.035)	0.624*** (0.035)	0.620*** (0.036)	0.615*** (0.035)	0.613*** (0.035)	0.618*** (0.035)
<i>Sales</i>	0.208*** (0.033)	0.211*** (0.032)	0.200*** (0.032)	0.202*** (0.032)	0.215*** (0.033)	0.218*** (0.032)	0.207*** (0.032)	0.208*** (0.031)
<i>Ret. earnings</i>	0.004 (0.022)	-0.004 (0.022)	-0.002 (0.021)	-0.007 (0.021)	0.004 (0.022)	-0.004 (0.021)	-0.002 (0.021)	-0.007 (0.021)
<i>EBITDA</i>	-0.246* (0.129)	-0.232* (0.128)	-0.205 (0.128)	-0.198 (0.129)	-0.297** (0.126)	-0.283** (0.125)	-0.256** (0.124)	-0.249** (0.125)
<i>Cash</i>	0.251 (0.186)	0.305* (0.180)	0.360** (0.178)	0.309* (0.180)	0.218 (0.190)	0.273 (0.185)	0.329* (0.182)	0.284 (0.185)
<i>Tangible</i>	0.428** (0.214)	0.392* (0.210)	0.341 (0.210)	0.292 (0.214)	0.500** (0.212)	0.465** (0.208)	0.415** (0.208)	0.363* (0.212)
<i>MtoB</i>	0.023*** (0.004)	0.023*** (0.004)	0.023*** (0.004)	0.023*** (0.004)	0.023*** (0.004)	0.023*** (0.004)	0.023*** (0.004)	0.023*** (0.004)
<i>HHI</i>	-0.677 (0.577)	-0.557 (0.572)	-0.525 (0.574)	-0.679 (0.562)	-0.507 (0.579)	-0.385 (0.574)	-0.354 (0.576)	-0.530 (0.563)
<i>HHI</i> ²	0.273 (0.696)	0.157 (0.699)	0.115 (0.708)	0.369 (0.681)	0.068 (0.698)	-0.051 (0.701)	-0.091 (0.712)	0.190 (0.680)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	58,349	58,349	58,349	57,831	58,349	58,349	58,349	57,831
Log Likelihood	-226,900.4	-225,474.5	-224,446.4	-220,149.1	-234,580.6	-233,043.8	-231,953.1	-227,580.7
Akaike Inf. Crit.	454,292.8	451,443.1	449,388.8	440,796.1	469,653.3	466,581.7	464,402.2	455,659.4

Note: This table presents the results of the Poisson regression of the model presented in equation (3.1). *Cites Time* $t+1$ computes the round number of time-adjusted citations received by the firm's patents. *Cites Time Class* $t+1$ computes the round number of time and class adjusted citations received by the firm's patents. *Public equity* is the ratio between shareholder equity and total assets. *Public debt* is the ratio between the outstanding amount of bonds and total assets. *Public debt*² is the square term of the *Public debt* variable. *Convertible* is the ratio between the book value of convertible debt and total assets. *R&D* is the log of 1+R&D expenses. *Sales* is the log of 1+Total sales. *Ret.earning* is the ratio between retained earnings and total assets. *EBITDA* is the ratio between EBITDA and total assets. *Cash* is the ratio between the amount of cash available and total assets. *Tangible* is the ratio between PPE and total assets. *MtoB* is the ratio between market capitalization and book value of equity. *HHI* is the Herfindahl index based on total sales and *HHI*² its square term. Significance levels: *p<0.1; **p<0.05; ***p<0.01

4.2. Studying the shape of the relation between public debt and innovation

In this section, we analyze the shape of the relationship between innovation and public debt. Following the methodology of Aghion *et al.* (2005), who study the link between competition and innovation, we investigate our relation in four ways. The Table 3.4 summarizes our results.

In Panel A, we ran our regression based on the model presented in equation (3.1). We then restricted our regression to the most innovative industries (Panel B)²³. In Panel C, we run our regression on the whole sample but we make a slight modification of the equation (3.1). Instead of using a squared term of *Public debt* we used a dummy variable equal to one if the firm has issued public debt over the past. Lastly, in Panel D, we inspect the inverse relation by regressing the ratio of public debt on the R&D intensity of a firm.

Our results illustrate our hypothesis of a nonlinear relationship between innovation and public debt. Indeed, in both the full and the top innovators samples (Panel A and B) we find a positive and significant coefficient for the Public debt variable and a negative and significant coefficient for the square of public debt. This indicates that the influence of the public debt variable is decreasing as the level of public debt rises. Such findings are similar to our baseline results in the previous section. However, thanks to Panel B we have an effective robustness check for this finding.

In Panel C, the positive and significant coefficient for the dummy variable indicates that companies using public debt tend to have greater innovation output. However, as the variable public debt is associated with a negative coefficient, it shows that the positive aspect of public debt on innovation diminishes as the level of debt increases.

In Panel D we use *Public debt* as a dependent variable and regress the *R&D dummy* and the *R&D intensity* on it. This model aims at studying the relationship for companies that invest heavily in their innovation strategy. We find that the R&D dummy variable has a positive and significant coefficient, suggesting that companies with R&D expenses use public debt. However, the variable R&D intensity is associated with a negative coefficient. This implies that

²³ We identified the most innovative industries by computing the sum of patents and citations in each industry and retained the top 5. The following industries were used in Panel B of Table 3.4: 357 (Computer and office equipment), 737 (Miscellaneous Equipment Rental and Leasing), 360 (Water Collection treatment and supply), 367 (Electronic Component and Accessories), 283 (Drugs).

greater levels of R&D spending relative to the value of the firm's asset are not financed through public debt.

Our findings suggest that public debt is not useful to firms that wish to have a strong and very successful innovation policy. At a certain point, a higher level of public debt does not imply a greater level of innovation output. One interpretation of such finding can be found in the paper of Aghion *et al.* (2004). The results of this paper describe that firms first prefer to issue debt rather than equity because it involves giving up less control rights of the firm. However, firms that innovate more tend to use equity over debt because they represent a greater risk compared to non-innovative firms. In such situations, only equity investors would be willing to take great risks given the payoff they may have in return.

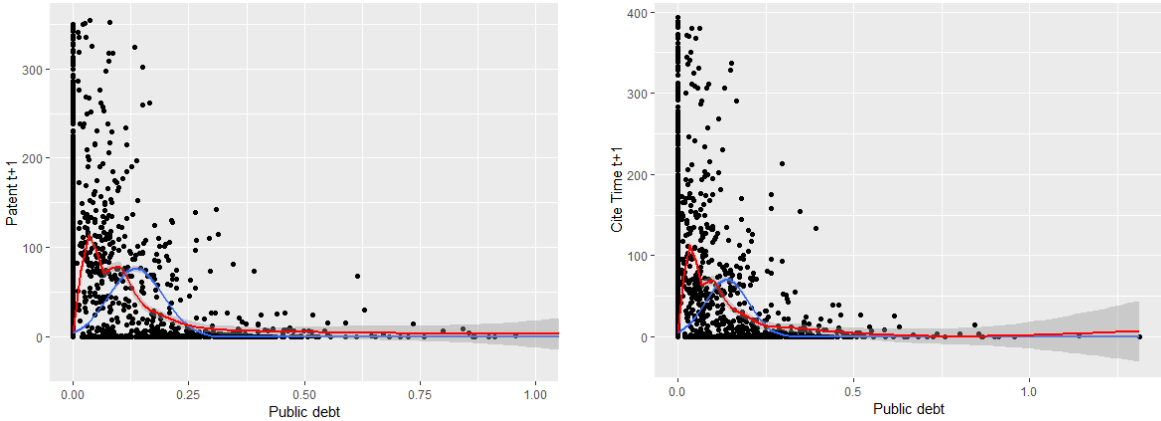
Table 3.4: Inverted U-shape relationship between public debt and innovation

	<i>Patents</i> (1)	<i>Cites Time_{t+1}</i> (2)	<i>Cites Class_{t+1}</i> (3)	<i>R&D</i> (4)
<u>Panel A: Full Sample</u>				
<i>Public debt</i>	32.453*** (1.931)	32.781*** (1.987)	32.596*** (1.957)	25.547*** (1.406)
<i>Public debt 2</i>	-119.050*** (9.156)	-121.063*** (9.435)	-120.381*** (9.262)	-79.324*** (4.660)
Year x Indus FE	Yes	Yes	Yes	Yes
Observations	144,312	144,312	144,312	83,572
Model	Poisson	Poisson	Poisson	OLS
<u>Panel B: Top innovators</u>				
<i>Public debt</i>	38.974*** (3.310)	36.668*** (3.312)	37.194*** (3.356)	40.780*** (4.300)
<i>Public debt 2</i>	-140.854*** (17.793)	-130.719*** (16.876)	-133.010*** (17.246)	-123.517*** (13.998)
Year x Indus FE	Yes	Yes	Yes	Yes
Observations	26,138	26,138	26,138	23,010
Model	Poisson	Poisson	Poisson	OLS
<u>Panel C: Dummy variable</u>				
<i>Public debt</i>	-5.620*** (0.552)	-5.809*** (0.533)	-5.753*** (0.537)	-6.138*** (0.533)
<i>Public debt dum</i>	2.515** (0.121)	2.531*** (0.121)	2.518*** (0.120)	2.478*** (0.138)
Year x Indus FE	Yes	Yes	Yes	Yes
Observations	144,312	144,312	144,312	83,572
Model	Poisson	Poisson	Poisson	OLS
<u>Panel D: R&D intensity</u>				
Dependent var.	<i>Public debt</i>			
<i>R&D dummy</i>	0.004** (0.002)			
<i>R&D intensity</i>	-0.018*** (0.001)			
Year x Indus FE	Yes			
Observations	83,572			
Model	OLS			

Note: This table presents the results used to demonstrate the inverted-U shape of the relationship between public debt and innovation. *Cites Time_{t+1}* computes the round number of time-adjusted citations received by the firm's patents. *Cites Time Class_{t+1}* computes the round number of time and class adjusted citations received by the firm's patents. *Public debt* is the ratio between the outstanding amount of bonds and total assets. *Public debt*² is the square term of the *Public debt* variable. *Public debt dum* is a dummy variable equal to one if the firm has issued public debt in the past. Panel A and C make estimation based on the whole sample. Panel B uses only firms that belong to five most innovative industries. Panel D uses the *Public debt* variable as a dependent variable. *R&D dummy* is equal to one if the firm has ever recorded a positive amount of R&D. *R&D intensity* is the ratio between the R&D expenses and the book value of assets. Significance levels: *p<0.1; **p<0.05; ***p<0.01.

Below we show two representations of data for the innovative industries sample. The blue line is the result of our model specification. The red line is the fitted specification that uses every data point without any assumptions to fit the data. These plots show the concave shape of the relationship between innovation and public debt.

Figure 3.2: Number of patents and citations in relation with the level of public debt



4.3. Bondholders in highly leveraged firms: a solution to risk-averse behaviors

This section is dedicated to the study of the relationship between debt and innovation in situations of high leverage. We detailed the evolution of the relationship found in the baseline results depending on the firm’s leverage ratio. We assume that a higher leverage ratio leads to a situation in which both managers and debtholders would prevent the firm from taking greater risk and thus investing less in innovation. However public debt, being synonymous with greater flexibility and tolerance for failure, could attenuate the negative impact of leverage and improve innovation activities within the firm.

Our objective is to study how firms interact with innovation when they face high financial risk. Therefore, we created subsamples by including firms relative to their debt-to-assets ratio. We have three subsamples of firms with a leverage ratio above the median of the sample, above the seventy-fifth percentile, and above the ninetieth percentile. The percentiles’ values are respectively 22.4%, 39.6%, and 52.3%. Furthermore, the number of firms in our subsamples is sufficient to run our regressions. In each subsample the number of firms is respectively the following: 5,504; 3,287 and 1,460.

Tables 3.5 and 3.6 describe the impact of leverage ratio on the number of patents and citations, respectively. In every model of both tables, the value of the public equity variable is positive and significant. The influence of equity financing is robust to the leverage ratio of the firm. However, we see the value of the coefficient associated with the *Public Debt* variable decrease as the samples are restricted to more highly leveraged firms.

In Table 3.5, which describes the influence of public debt on the number of patents, *Public Debt* is positive and significant only in the first model based on the sample of firms above the median of leverage. In highly leveraged firms the value of the coefficient is smaller and not significant. In the models based on the adjusted number of citations (Table 3.6) we find similar results: only the sample of firms above the sample's median has a positive and significant coefficient for the *Public Debt* variable. Our second testable hypothesis (H2a) does not find support.

Our results on the influence of convertible debt on the number of patents are similar to our baseline results. The coefficient associated with the variable is not significant for each model of Table 3.5. The presence of a convertible debt had no impact on the number of patents applied by the firm. In the citation models of Table 3.6, the coefficient of the convertible debt variable is no longer significant, while it was positive and significant in the baseline results. As the leverage of the company increased, the mitigating effect of convertible debt was no longer effective. It did not promote greater risk-taking when the firm was already facing a certain level of risk with its leverage ratio. According to these results, our second hypothesis (H2b), describing the evolution of the convertible debt's impact as the leverage ratio increases, is not validated.

Table 3.5: Debt composition in highly leveraged firms – number of patents

	Above median	Above 75th percentile	Above 90th percentile
	(1)	$Patent_{t+1}$ (2)	(3)
<i>Public equity</i>	0.860*** (0.217)	0.466** (0.187)	0.371** (0.176)
<i>Public debt</i>	1.415*** (0.377)	0.073 (0.427)	0.792 (0.652)
<i>Convertible</i>	-0.001 (0.413)	-0.004 (0.721)	-0.769 (1.142)
<i>R&D</i>	0.585*** (0.043)	0.778*** (0.070)	0.843*** (0.085)
<i>Sales</i>	0.306*** (0.040)	0.208*** (0.061)	0.183** (0.074)
<i>Ret. earnings</i>	-0.041 (0.032)	-0.030 (0.034)	0.023 (0.039)
<i>EBITDA</i>	-0.100 (0.214)	0.103 (0.165)	-0.212 (0.188)
<i>Cash</i>	0.186 (0.474)	1.263 (0.775)	2.514*** (0.670)
<i>Tangible</i>	0.465* (0.245)	-0.202 (0.380)	0.147 (0.623)
<i>MtoB</i>	0.013** (0.006)	0.007 (0.006)	-0.002 (0.006)
<i>HHI</i>	-0.250 (0.682)	0.702 (0.914)	-0.057 (2.069)
<i>HHI2</i>	0.067 (0.717)	-0.849 (1.045)	-0.729 (2.502)
Year FE	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes
Number of firms	5,504	3,287	1,460
Observations	24,472	9,954	3,352
Log Likelihood	-73,368.500	-16,416.290	-3,199.956
Akaike Inf. Crit.	152,227.000	33,316.570	6,809.912

Note: This table presents the results of the Poisson regression of the model presented in equation (3.1) for the high leveraged firms. Subsamples were created based on the value of the debt-to-assets ratio. $Patent_{t+1}$ computes the round number of patents applied by a firm. *Public equity* is the ratio between shareholder equity and total assets. *Public debt* is the ratio between the outstanding amount of bonds and total assets. $Public\ debt^2$ is the square term of the *Public debt* variable. *Convertible* is the ratio between the book value of convertible debt and total assets. *R&D* is the log of 1+R&D expenses. *Sales* is the log of 1+Total sales. *Ret.earning* is the ratio between retained earnings and total assets. *EBITDA* is the ratio between EBITDA and total assets. *Cash* is the ratio between the amount of cash available and total assets. *Tangible* is the ratio between PPE and total assets. *MtoB* is the ratio between market capitalization and book value of equity. *HHI* is the Herfindahl index based on total sales and HHI^2 its square term. Significance levels: *p<0.1; **p<0.05; ***p<0.01

Table 3.6: Debt composition in highly leveraged firms – Number of citations

	Above median		Above 75 th percentile		Above 90 th percentile	
	<i>Cites Time</i> _{<i>t+1</i>}	<i>Cites Time Class</i> _{<i>t+1</i>}	<i>Cites Time</i> _{<i>t+1</i>}	<i>Cites Time Class</i> _{<i>t+1</i>}	<i>Cites Time</i> _{<i>t+1</i>}	<i>Cites Time Class</i> _{<i>t+1</i>}
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Public equity</i>	1.088*** (0.251)	1.029*** (0.243)	0.453** (0.207)	0.492** (0.204)	0.476** (0.214)	0.454** (0.201)
<i>Public debt</i>	1.320*** (0.411)	1.309*** (0.416)	-0.050 (0.501)	-0.089 (0.492)	-0.277 (1.015)	-0.297 (0.984)
<i>Convertible</i>	0.472 (0.418)	0.353 (0.424)	0.384 (0.604)	0.396 (0.627)	0.467 (1.012)	0.641 (1.028)
<i>R&D</i>	0.609*** (0.047)	0.601*** (0.046)	0.817*** (0.067)	0.815*** (0.066)	0.868*** (0.099)	0.874*** (0.096)
<i>Sales</i>	0.257*** (0.043)	0.262*** (0.042)	0.165*** (0.055)	0.157*** (0.054)	0.182** (0.089)	0.163* (0.092)
<i>Ret. earnings</i>	-0.067** (0.031)	-0.066** (0.031)	-0.028 (0.035)	-0.034 (0.035)	-0.003 (0.038)	-0.001 (0.039)
<i>EBITDA</i>	-0.040 (0.226)	-0.054 (0.221)	-0.027 (0.231)	-0.002 (0.228)	-0.433 (0.267)	-0.391 (0.270)
<i>Cash</i>	0.146 (0.430)	0.094 (0.437)	1.043 (0.638)	1.102* (0.619)	1.715** (0.702)	1.804** (0.708)
<i>Tangible</i>	0.507* (0.272)	0.526* (0.270)	0.342 (0.435)	0.299 (0.424)	0.575 (0.861)	0.488 (0.789)
<i>MtoB</i>	0.016** (0.007)	0.016** (0.007)	0.010 (0.009)	0.006 (0.009)	-0.006 (0.014)	-0.010 (0.013)
<i>HHI</i>	-0.651 (0.712)	-0.623 (0.725)	0.507 (1.022)	0.561 (1.028)	3.181 (2.476)	2.808 (2.465)
<i>HHI2</i>	0.313 (0.794)	0.200 (0.808)	-0.986 (1.215)	-1.105 (1.213)	-5.700* (3.428)	-5.484 (3.463)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of firms	5,504	5,504	3,287	3,287	1,460	1,460
Observations	23,148	23,148	9,302	9,302	3,050	3,050
Log Likelihood	-75,501.320	-79,350.310	-16,628.990	-17,600.710	-3,309.301	-3,444.289
Akaike Inf. Crit.	151,492.600	159,190.600	33,739.980	35,683.420	7,024.602	7,294.578

Note: This table presents the results of the Poisson regression of the model presented in equation (3.1) for the high leveraged firms. Subsamples were created based on the value of the debt-to-assets ratio. *Cites Time*_{*t+1*} computes the round number of time-adjusted citations received by the firm's patents. *Cites Time Class*_{*t+1*} computes the round number of time and class adjusted citations received by the firm's patents. *Public equity* is the ratio between shareholder equity and total assets. *Public debt* is the ratio between the outstanding amount of bonds and total assets. *Public debt*² is the square term of the *Public debt* variable. *Convertible* is the ratio between the book value of convertible debt and total assets. *R&D* is the log of 1+R&D expenses. *Sales* is the log of 1+Total sales. *Ret.earning* is the ratio between retained earnings and total assets. *EBITDA* is the ratio between EBITDA and total assets. *Cash* is the ratio between the amount of cash available and total assets. *Tangible* is the ratio between PPE and total assets. *MtoB* is the ratio between market capitalization and book value of equity. *HHI* is the Herfindahl index based on total sales and *HHI*² its square term. Significance levels: *p<0.1; **p<0.05; ***p<0.01

4.4. Public debt as a solution to the conflict between shareholders and creditors?

In this section, we explore the relationship between public debt and innovation when firms are in operational difficulty. We do not study firms that have filed for the bankruptcy according to US regulation (chapter 7 or 11). However, we use different proxies that indicate that a firm faces operational difficulty and may be in a situation where market value of its assets is stressed. We evaluated the operational difficulties that firms face using three distinct criteria.

First, we identified firms having a negative book value of equity. Typically, firms are in this situation due to significant amount of negative retained earnings that have been accumulated over the years. This sample is composed of 2,513 observations and 1,233 unique firms.

Second, we considered firms with a market-to-book ratio below one. Such firms have an enterprise value lower than the book value of their assets, indicating that the firm is not able to generate value from its activities. This sample is composed of 16,255 observations and 4,885 unique firms.

Third, we selected firms with negative operational cash flow. Such companies do not generate cash flow from their operations because their revenue is not high enough to cover the expenses or because they suffer from long-delayed payments from their suppliers. 14,315 observations and 4,646 unique firms constitute this sample.

Such situations enabled us to study the behavior of creditors when the firm is approaching its default region. In this region, shareholders and debtholders have contradictory incentives (Myers, 1977): shareholders encourage risky investments and therefore innovation, while debtholders prevent such investments. Innovation could be seen as a way to improve the firm's situation. Greater levels of innovation reflect a greater level of future opportunities and positive cash flows. Firms in difficulty may wish to innovate more in order to improve their operations.

Such firms may find it difficult to raise external traditional financing since they represent a great risk. However, one could expect that bondholders and creditors with an ability to convert their debt into equity may be inclined to allow the firm to invest in innovation projects.

Relative to patents (Table 3.7), we found that the *Public Debt* variable has a positive and significant coefficient only in the subsample created with the market-to-book ratio. In other samples, the coefficient is not significant. Two out of three samples indicated that the variable had no effect on corporate innovation.

Regarding the adjusted number of citations (Table 3.8), we found that *Public Debt* has a positive and significant coefficient in models based on the market-to-book subsample (columns 3 and 4). In the subsample of negative book value of equity the coefficients are negative and significant. Last, the coefficients are positive in the subsample of firms having negative cash flow but not significant. This is slightly different from the models describing the number of patents. As a consequence, one could say that when faced with operational difficulty the ability of public debt to promote innovation does not seem to hold. Our third hypothesis (H3a) does not have support.

The *Convertible* variable was not significant in any of the models presented in Table 3.7 indicating that it has no influence on the volume of innovations within the corporation.

However, in our citations based models (Table 3.8), we see that it has a positive and significant coefficient in every subsamples created. Similar to our baseline results, convertible debt seemed to play a role only on the quality of innovation rather than the number of patents applied. Such results show support for a positive influence of convertible debt on innovation, supporting the hypothesis that it attenuates the divergence in interest between shareholders and debtholders in the default region.

Convertible debt might be able to mitigate the risk shifting incentives of shareholders. Such risk-shifting occurs when shareholders increase the risk of the firm and transfer value from the debtholders. Because the value of equity increases with risk, but the value of debt decreases with it, shareholders might have incentives to increase the level of risk taken by the firm. Managers of the firm, who represent shareholders, would invest in projects with negative Net Present Value. Therefore, the total value of the firm would be lower but there would have been a transfer of value from debtholder to shareholders.

Because we observe no significant coefficients of the convertible debt variable in models based on the number of patent but positive and significant coefficients for models with the number of citations, one can say that convertible debt is enhancing the quality of innovation project without increasing the level of risk of the firm (i.e. driving upward the level of patents applied).

According to Green (1984), the ability of convertible debt to mitigate asset substitution incentives remains in the potential dilution of equity if the option is exercised. If the equity value is above the strike price of the option, convertible debt investors will exercise their option and convert their debt into equity. Consequently, new shares are issued and the previous

shareholders are diluted. Convertible debt alters the form of the payoff function of equity, reducing their incentive to implement risk-shifting.

Additionally, if the value of equity is below the strike price and the option to convert is not used, convertible debt investors remain creditors of the firm. Consequently they have an incentive to prevent the shareholders from taking excessive risk at the expense of the value of their claim. Overall, our third hypothesis (H3b) is validated by our findings.

Table 3.7: Debt composition in firms in difficulty – Number of patents

	Book value equity<0 (1)	MtoB<1 <i>Patent_{t+1}</i> (2)	Negative cash-flow (3)
<i>Public equity</i>	0.139 (0.151)	0.779*** (0.176)	0.528* (0.270)
<i>Public debt</i>	0.022 (1.039)	1.602*** (0.521)	-0.289 (0.568)
<i>Convertible</i>	-0.408 (1.233)	-0.087 (0.665)	0.494 (0.527)
<i>R&D</i>	0.945*** (0.117)	0.513*** (0.062)	0.874*** (0.039)
<i>Sales</i>	0.052 (0.114)	0.380*** (0.061)	0.095*** (0.033)
<i>Ret. earnings</i>	0.037 (0.035)	-0.059* (0.033)	0.036* (0.018)
<i>EBITDA</i>	0.159 (0.195)	-0.137 (0.227)	0.125 (0.112)
<i>Cash</i>	1.446** (0.662)	0.073 (0.609)	0.415** (0.190)
<i>Tangible</i>	-0.069 (0.490)	0.596* (0.349)	0.380 (0.259)
<i>MtoB</i>	-0.039* (0.020)	-0.050*** (0.019)	0.018*** (0.004)
<i>HHI</i>	-2.405 (2.149)	-0.762 (0.902)	0.299 (1.041)
<i>HHI²</i>	3.066 (2.236)	0.610 (0.968)	-1.035 (1.348)
Year FE	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes
Number of firms	1,233	4,885	4,646
Observations	2,513	16,255	14,315
Log Likelihood	-1,977.109	-35,956.860	-26,560.620
Akaike Inf. Crit.	4,348.218	72,403.720	53,555.240

Note: This table presents the results of the Poisson regression of the model presented in equation (3.1) for firms facing difficulties. Subsamples were created using the book value of equity, market-to-book ratio and operational cash flow. *Patent_{t+1}* computes the round number of patents applied by a firm. *Public equity* is the ratio between shareholder equity and total assets. *Public debt* is the ratio between the outstanding amount of bonds and total assets. *Public debt²* is the square term of the *Public debt* variable. *Convertible* is the ratio between the book value of convertible debt and total assets. *R&D* is the log of 1+R&D expenses. *Sales* is the log of 1+Total sales. *Ret.earning* is the ratio between retained earnings and total assets. *EBITDA* is the ratio between EBITDA and total assets. *Cash* is the ratio between the amount of cash available and total assets. *Tangible* is the ratio between PPE and total assets. *MtoB* is the ratio between market capitalization and book value of equity. *HHI* is the Herfindahl index based on total sales and *HHI²* its square term. Significance levels: *p<0.1; **p<0.05; ***p<0.01

Table 3.8: Debt composition in firms in difficulty – Number of citations

	Book value equity<0		MtoB<1		Negative cash-flow	
	<i>Cites Time</i> _{t+1}	<i>Cites Time Class</i> _{t+1}	<i>Cites Time</i> _{t+1}	<i>Cites Time Class</i> _{t+1}	<i>Cites Time</i> _{t+1}	<i>Cites Time Class</i> _{t+1}
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Public equity</i>	0.134 (0.217)	0.082 (0.203)	0.808*** (0.186)	0.784*** (0.184)	0.879*** (0.235)	0.780*** (0.244)
<i>Public debt</i>	-2.169* (1.128)	-1.950* (1.167)	1.191* (0.652)	1.124* (0.630)	-0.078 (0.792)	-0.127 (0.778)
<i>Convertible</i>	2.238*** (0.836)	2.186** (0.878)	1.783** (0.850)	1.808** (0.874)	1.093* (0.621)	1.093* (0.630)
<i>R&D</i>	1.104*** (0.136)	1.136*** (0.143)	0.583*** (0.063)	0.591*** (0.066)	0.814*** (0.048)	0.830*** (0.049)
<i>Sales</i>	-0.016 (0.122)	-0.076 (0.127)	0.312*** (0.061)	0.294*** (0.066)	0.103** (0.040)	0.084** (0.041)
<i>Ret. earnings</i>	0.033 (0.037)	0.037 (0.036)	-0.068** (0.032)	-0.068** (0.032)	0.028 (0.023)	0.030 (0.023)
<i>EBITDA</i>	0.162 (0.172)	0.209 (0.164)	-0.028 (0.216)	-0.042 (0.213)	0.017 (0.150)	0.031 (0.140)
<i>Cash</i>	1.308** (0.660)	1.404** (0.659)	0.362 (0.557)	0.353 (0.585)	0.454* (0.234)	0.426* (0.241)
<i>Tangible</i>	-0.450 (0.642)	-0.499 (0.626)	0.892*** (0.345)	0.902** (0.355)	0.385 (0.360)	0.336 (0.342)
<i>MtoB</i>	-0.033 (0.025)	-0.040 (0.027)	-0.053*** (0.020)	-0.058*** (0.020)	0.026*** (0.007)	0.023*** (0.008)
<i>HHI</i>	-2.166 (2.293)	-2.615 (2.313)	-1.395 (0.990)	-1.098 (0.981)	-0.438 (1.073)	-0.326 (1.137)
<i>HHI2</i>	2.301 (2.399)	2.559 (2.415)	0.904 (1.062)	0.649 (1.054)	0.032 (1.385)	-0.409 (1.486)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Indus FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of firms	1,233	1,233	4,885	4,885	4,646	4,646
Observations	2,207	2,207	15,031	15,031	12,572	12,572
Log Likelihood	-1,899.299	-1,992.162	-33,852.040	-35,575.580	-31,417.030	-32,464.770
Akaike Inf. Crit.	4,174.597	4,360.325	68,194.090	71,641.150	63,266.060	65,361.540

Note: This table presents the results of the Poisson regression of the model presented in equation (3.1) for firms facing difficulties. Subsamples were created using the book value of equity, market-to-book ratio and operational cash flow. *Cites Time*_{t+1} computes the round number of time-adjusted citations received by the firm's patents. *Cites Time Class*_{t+1} computes the round number of time and class adjusted citations received by the firm's patents. *Public equity* is the ratio between shareholder equity and total assets. *Public debt* is the ratio between the outstanding amount of bonds and total assets. *Public debt*² is the square term of the *Public debt* variable. *Convertible* is the ratio between the book value of convertible debt and total assets. *R&D* is the log of 1+R&D expenses. *Sales* is the log of 1+Total sales. *Ret.earning* is the ratio between retained earnings and total assets. *EBITDA* is the ratio between EBITDA and total assets. *Cash* is the ratio between the amount of cash available and total assets. *Tangible* is the ratio between PPE and total assets. *MtoB* is the ratio between market capitalization and book value of equity. *HHI* is the Herfindahl index based on total sales and *HHI*² its square term. Significance levels: *p<0.1; **p<0.05; ***p<0.01

5. Other empirical specifications

5.1. Taking care of the endogeneity in the choice of the financial structure

In the section we perform a robustness check for the baseline result. We use the instrumental methodology to deal with endogeneity of the leverage ratio of firms.

Financial structure of firms might be endogenous, especially, the level of leverage might depend on variables that are not taken into account in our models. One element that might influence the leverage of a firm is the cost of debt. This element reflects the level of risk of the firm from the creditor's point of view and is represented by the interest rate asked by the lenders.

We use the variable describing the cost of debt of the firm as an instrument. Following Pittman and Fortin (2004), such a variable is computed as the ratio between the total interest expense and the total debt of the firm.

We believe this instrument is relevant because it results from the analysis done by external stakeholders. As a consequence it can be considered endogenous. It is not likely to directly influence innovation policies of firms but has a direct influence of the debt structure. The table below summarizes the results obtained when performing the Two-Stage Least Square method for instrumental variables.

We still find a positive and significant coefficient for the variable public debt after controlling for endogeneity.

Table 3.9: 2SLS instrumental variable

	<i>Public debt</i>	<i>Patents</i>	<i>Cites Time_{t+1}</i>	<i>Cites Class_{t+1}</i>
	(1)	(2)	(3)	(4)
<i>Cost of Debt</i>	-0.005*** (0.001)			
<i>Public equity</i>	-0.016*** (0.001)	1.412*** (0.417)	1.720*** (0.427)	1.728*** (0.432)
<i>Public debt fitted</i>		49.984** (23.616)	58.889** (24.099)	60.471** (24.443)
Hausman test (p-value)		0.000	0.000	0.000
Year and Indus FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	52,784	52,784	52,784	52,784
R ²	0.123			
Log Likelihood		-178,249.3	-201,283.6	-207,665.0

Note: This table presents the results of the 2SLS methodology for Instrumental Variables. The first column is the first stage of the methodology where we regress our instrument on the endogenous variable. Our instrument is the *Cost of debt* and is computed as the ratio between the total interest expense bear by a firms and its total debt. *Patent_{t+1}* computes the round number of patents applied by a firm. *Cites Time_{t+1}* computes the round number of time-adjusted citations received by the firm's patents. *Cites Time Class_{t+1}* computes the round number of time and class adjusted citations received by the firm's patents. *Public equity* is the ratio between shareholder equity and total assets. *Public debt* is the ratio between the outstanding amount of bonds and total assets. *Convertible* is the ratio between the book value of convertible debt and total assets.

5.2. Focusing on the input of innovation

In this section we analyze the input of innovation (e.g. R&D expenses) rather than its output (e.g. patents and citations). When using the number of patent applications and the number of citations, we focus only on successful innovations. However, there are numerous inventions that do not get patented. With R&D expenses as a dependent variable we are able to study innovation in a broader definition by including unsuccessful innovations. The table below summarizes our result when firms face financial difficulty (Panel A) and operational difficulty (Panel B).

We find little evidence of the influence of the public debt variable on R&D expenses. As a matter of fact, only one model out of the six presented above show a significant coefficient (column 3 in Panel B). It seems that the financing through public debt is not used to finance R&D expenses when firms face high risk. This is consistent with our previous results based on the output of innovation.

However, we observe positive and significant coefficients in every model for the variable of convertible debt. This is consistent with our result based on citations and patents for firms in

difficulty. Nonetheless, a slight difference occurs when we look at the firm facing high leverage. We find a positive influence of the convertible variable, while before we found no significant results.

Table 3.10: Debt composition's influence on R&D expenses

Panel A: Leverage ratio			
	Above median	Above 75th percentile	Above 90th percentile
	(1)	(2)	(3)
<i>Public equity</i>	0.164*** (0.029)	0.095*** (0.030)	0.108*** (0.032)
<i>Public debt</i>	0.045 (0.206)	-0.073 (0.222)	0.408 (0.331)
<i>Convertible</i>	0.598*** (0.112)	0.719*** (0.107)	0.737*** (0.130)
Year and Indus FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	26,054	10,760	3,684
R ²	0.726	0.633	0.564
F Statistic	281.506***	75.466***	21.493***
Panel B: Firms in difficulty			
	Book value equity <0	MtoB<1	Negative cashflow
	(1)	(2)	(3)
<i>Public equity</i>	0.014 (0.026)	0.211*** (0.024)	0.309*** (0.023)
<i>Public debt</i>	0.574 (0.483)	-0.270 (0.285)	0.575* (0.341)
<i>Convertible</i>	0.613*** (0.140)	0.427*** (0.136)	0.598*** (0.124)
Year and Indus FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	2,875	17,458	15,472
R ²	0.642	0.673	0.511
F Statistic	23.824***	145.728***	73.084***

Note: This table presents the results of the Poisson regression of the model presented in equation (3.1) with R&D expenses as the dependent variable. Panel A describes the firms based on their leverage ratio. Subsamples were defined according to the median, 75th percentile and the 90th percentile computed on the whole sample. Panel B describes firms in difficulty. Subsamples were created using the book value of equity, market-to-book ratio and operational cash flow. *Public equity* is the ratio between shareholder equity and total assets. *Public debt* is the ratio between the outstanding amount of bonds and total assets. *Public debt*² is the square term of the *Public debt* variable. *Convertible* is the ratio between the book value of convertible debt and total assets. All regressions include the same controls used in previous tables of the paper. Significance levels: *p<0.1; **p<0.05; ***p<0.01

6. Conclusion

Our paper highlighted the role of public and convertible debt in the innovation policy of firms. Our results support the findings of Atanassov (2015): the amount of public debt within a firm has a positive and significant influence on both the number of patents and citations received. However, we add to this finding by demonstrating the existence of a non-linear relationship between the outstanding amount of debt and corporate innovation. This provides support for the findings of Aghion *et al.* (2004). Companies do not rely exclusively on public debt to finance innovative projects. Our results suggest that public debt is used for innovation until a certain point. Consequently, the greater tolerance for risk inherent to public debt does not seem to hold.

When focusing on firms with high leverage ratios that might face a debt overhang issue, we see that the positive influence of public debt disappears. We observe a loss of significant result for the public debt variable when a company has a leverage ratio above the 75th percentile in both models based on the number of patents and the number of citations as well as the level of R&D expenses. We also find no significant results for the convertible debt variable, except for R&D expenses for which we observe a positive impact. These findings suggest that public and convertible debts have a limited ability to incentive firms facing risk adversity, due to their leverage, to take greater risk and invest in innovation.

Lastly, we study the influence of the type of debt in firms facing shareholder-creditor conflicts. We find little evidence of the public debt variable in mitigating such conflicts. When analyzing the convertible debt ratio we find that the variable is positively influencing corporate innovation. Yet, the effect of convertible debt is only positive with the number of citations received by the patents of the firm and the level of R&D expenses but not the number of patents applied by a firm. Convertible bonds do not impact the number of risky projects (i.e. the number of patents) but rather improve their quality. The nature of the convertible option to enjoy the upside of value in the case of success of the innovative project and dilute current shareholders, while being protected (and not exercise the option) when the project fails enables such investors to enhance corporate innovation. Consequently, investors would exercise their option and dilute current shareholders if the project succeeds. Therefore, current shareholders would not be the only stakeholder to enjoy the success of an innovative project and decrease their incentive to implement risk-shifting behaviors.

Our paper may have a limitation in the way we define firms facing shareholder-creditor conflicts (i.e. firms with operational difficulty). One may find better ways to create subsamples and identify such firms. An area of improvement of the paper remains in the study of effectively distressed firms. Future research could evaluate the mechanisms at play in the financial structure of firms that filed for bankruptcy.

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Appendices

Table 3.11: Definition of the variables

Variable	Definition	Source
Patents	Number of patents granted to the firm in a year	NBER
	Number of citations received by all the patents belonging to the firm in one year divided by the average number of citation received by all patents in the same year.	
Cites Time	The formula is the following: $\frac{\sum_i^{n_{ft}} Citation_i}{\sum_j^{N_t} Citation_j / N_t}$, with <i>Citations_i</i> is the number of citations received by i th patent from firm f, <i>n_{ft}</i> is the total number of patents applied for by firm f in year t. <i>Citations_j</i> is the number of citations received by j th patent applied in year t, and <i>N_t</i> is the total number of patent applied in year t.	NBER
	Number of citations received by all the patents belonging to the firm in one year divided by the average number of citation received by all patents in the same year.	
Cites Time Class	The formula is the following: $\sum_k^M \frac{\sum_i^{n_{fkt}} Citation_i}{\sum_j^{N_{kt}} Citation_j / N_{kt}}$, <i>Citations_i</i> is the number of citations received by i th patent from firm f, <i>n_{fkt}</i> is the total number of patent for firm f applied in year t in class k, <i>Citations_j</i> is the number of citations received by j th patent applied in year t, and <i>N_{kt}</i> is the total number of patent applied in year t in class k. M is the total number of patent classes in the data	NBER
Public debt	Ratio between the outstanding amount of bonds and the total assets	SDC Platinum/ Compustat
Public equity	Ratio between the shareholder equity and the total assets	Compustat
Debt ratio	Ratio between the total long term debt and total assets	Compustat
Convertible	Ratio of convertible debt on the total assets	Compustat
HHI	Herfindahl index computed with the sales and four-digit SIC codes	Compustat
Market to book	Ratio between the market capitalization and the total assets	Compustat
log(1+R&D)	Log of R&D expenses	Compustat
log(1+Sales)	Log of total sales	Compustat
Ret. Earnings	Ratio between Retained Earnings and total assets	Compustat
EBITDA	Ratio between EBITDA and total assets	Compustat
Cash	Ratio between cash and total assets	Compustat
Tangible	Ratio between PPE and total assets	Compustat

Table 3.12: Pearson correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 <i>Patents</i>	1.000														
2 <i>Cites Time</i>	0.589	1.000													
3 <i>Cites Time Class</i>	0.591	0.994	1.000												
4 <i>Public debt</i>	(0.001)	0.025	0.023	1.000											
5 <i>Public equity</i>	0.038	0.083	0.086	(0.066)	1.000										
6 <i>Debt ratio</i>	(0.016)	(0.051)	(0.049)	(0.794)	0.126	1.000									
7 <i>Convertible</i>	0.005	0.003	0.001	(0.175)	0.224	0.252	1.000								
8 <i>HHI</i>	0.360	0.595	0.600	0.099	0.158	(0.146)	0.005	1.000							
9 <i>Market to book</i>	0.192	0.316	0.322	0.044	0.229	(0.021)	(0.027)	0.601	1.000						
10 <i>log(I+R&D)</i>	0.031	0.061	0.062	0.559	0.051	(0.319)	(0.080)	0.142	0.388	1.000					
11 <i>log(I+Sales)</i>	0.033	0.064	0.064	0.397	0.059	(0.212)	(0.083)	0.110	0.439	0.678	1.000				
12 <i>Ret. Earnings</i>	(0.011)	(0.019)	(0.022)	0.130	(0.070)	(0.217)	(0.002)	0.030	(0.290)	(0.202)	(0.282)	1.000			
13 <i>EBITDA</i>	(0.003)	(0.003)	0.001	(0.033)	0.054	0.161	(0.006)	(0.009)	0.090	0.073	0.106	(0.288)	1.000		
14 <i>Cash</i>	0.011	0.023	0.022	0.136	(0.015)	(0.133)	0.011	0.034	(0.135)	(0.070)	(0.123)	0.186	(0.087)	1.000	
15 <i>Tangible</i>	0.025	0.031	0.031	(0.018)	(0.018)	0.018	0.008	(0.036)	(0.004)	0.030	0.039	(0.072)	(0.141)	(0.025)	1.000

Table 3.13: Spearman correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 <i>Patents</i>	1.000														
2 <i>Cites Time</i>	0.747	1.000													
3 <i>Cites Time Class</i>	0.747	1.000	1.000												
4 <i>Public debt</i>	0.079	0.079	0.078	1.000											
5 <i>Public equity</i>	0.174	0.171	0.172	(0.138)	1.000										
6 <i>Debt ratio</i>	(0.079)	(0.081)	(0.080)	(0.799)	0.152	1.000									
7 <i>Convertible</i>	0.063	0.062	0.062	(0.198)	0.186	0.251	1.000								
8 <i>HHI</i>	0.563	0.552	0.552	0.130	0.190	(0.164)	0.083	1.000							
9 <i>Market to book</i>	0.289	0.285	0.286	(0.162)	0.296	0.130	0.104	0.439	1.000						
10 <i>log(I+R&D)</i>	0.171	0.173	0.173	0.295	0.085	(0.217)	(0.063)	0.176	0.528	1.000					
11 <i>log(I+Sales)</i>	0.104	0.114	0.114	0.086	0.078	(0.052)	(0.036)	0.096	0.470	0.607	1.000				
12 <i>Ret. Earnings</i>	0.030	0.028	0.027	0.280	(0.091)	(0.359)	(0.047)	0.108	(0.214)	(0.144)	(0.124)	1.000			
13 <i>EBITDA</i>	(0.009)	(0.010)	(0.009)	(0.112)	0.081	0.249	0.030	(0.032)	0.173	0.148	0.186	(0.275)	1.000		
14 <i>Cash</i>	0.098	0.102	0.101	0.171	0.023	(0.219)	(0.043)	0.168	(0.045)	(0.085)	0.130	0.201	(0.114)	1.000	
15 <i>Tangible</i>	0.058	0.061	0.061	(0.043)	(0.017)	0.042	0.016	(0.016)	0.003	0.080	0.042	(0.077)	(0.130)	(0.049)	1.000

Conclusion générale

Ce travail de recherche s'est proposé de contribuer à l'étude de l'influence que peuvent avoir certains mécanismes de gouvernement d'entreprise sur les politiques d'innovation. Nous avons décliné notre étude en trois chapitres, chacun abordant un mécanisme en particulier.

Le premier article de cette thèse s'est proposé d'analyser la relation entre la structure actionnariale d'une entreprise et la mise en place d'une politique d'innovation ouverte spécifique, le capital-risque d'entreprise. Les actionnaires étant les propriétaires de l'entreprise ont intérêt à s'investir dans la gestion de l'entreprise afin d'améliorer la valeur de leur investissement. Dès lors, ils ont un rôle à jouer dans l'orientation des politiques d'innovation, source d'opportunités futures et de croissance pour l'entreprise. Les actionnaires peuvent intervenir directement en manifestant leur opposition à l'équipe dirigeante ou bien en quittant l'entreprise et en vendant leur participation. Notre étude se concentre sur les investisseurs institutionnels, considérés comme sophistiqués, capables d'obtenir des informations quant à l'entreprise et dotés d'un horizon d'investissement à long-terme. Le capital-risque d'entreprise, quant à lui, est un processus d'innovation impliquant la prise de participations minoritaires dans de jeunes entreprises. Ce processus d'innovation permet l'allocation de ressources internes à des entreprises externes. C'est donc un processus d'innovation à l'interface de processus internes (comme les dépenses en recherche et développement) et externes (l'acquisition et l'intégration d'entreprises disposant d'une technologie). Ce chapitre met en évidence l'influence positive des investisseurs institutionnels sur l'ouverture des structures de capital-risque d'entreprise. Nos résultats suggèrent que l'horizon d'investissement de ces investisseurs favorise la réduction de pression sur les dirigeants pour des objectifs à court terme, ainsi qu'un meilleur contrôle de ces dirigeants. Par ailleurs, il apparaît que cette relation positive est largement influencée par la présence d'actionnaires dit passifs au sein de l'entreprise. Ce chapitre permet de démontrer la pertinence de l'analyse de la structure actionnariale dans la définition de la politique d'innovation de l'entreprise.

Le second chapitre de cette thèse s'est attaché à étudier la composition des conseils d'administration, dont le rôle stratégique et de contrôle peut directement influencer la politique d'innovation. Nous nous demandons si le regroupement d'individus aux expériences et compétences diverses au sein du conseil d'administration est en mesure d'influencer la politique d'innovation d'une entreprise. Nous analysons cette composition selon différentes

dimensions : l'expertise industrielle, les expériences dans des entreprises de support (dans le secteur de la finance, la communication ou bien les institutions publiques) ainsi que la taille du réseau de connaissances professionnelles et extra-professionnelles. Ces éléments permettraient au conseil d'administration de réduire les coûts de transactions mais aussi les incertitudes relatives aux projets innovants. Par ailleurs, nous étudions l'influence des administrateurs en fonction de leur statut d'indépendant ou non. Notre recherche met en évidence un rôle appuyé du réseau des administrateurs indépendants dans le succès des politiques d'innovation : plus le réseau de ces administrateurs est important, plus l'entreprise innove. D'autre part, les administrateurs non indépendants semblent favoriser l'activité d'innovation grâce à leur expertise sectorielle. Dès lors, pour améliorer l'innovation d'une entreprise, le conseil d'administration semble devoir se doter d'individus disposant d'un réseau de connaissance suffisamment développé tout en se munissant de dirigeants dont l'expertise sectorielle est avérée.

Le troisième chapitre de la thèse s'est intéressé aux liens existants entre la structure de financement d'une entreprise et sa politique d'innovation. L'influence positive d'un financement par capitaux propres sur l'innovation ayant déjà été largement étudié par la littérature académique, nous nous sommes concentrés sur l'étude de l'effet d'un financement par dette obligataire et convertible. Ces types de dettes sont supposés garantir la présence d'investisseurs plus tolérants au risque que les institutions bancaires. Cela permettrait à l'entreprise d'entreprendre un plus grand nombre de projets innovants. Notre étude a révélé effectivement que la présence de dette obligataire favorise le succès de la politique d'innovation. Néanmoins, nous révélons également que cet effet positif a tendance à s'atténuer à mesure que l'entreprise a recours à de la dette obligataire : il existe une relation concave entre le recours à de la dette obligataire et le succès de la politique d'innovation. D'autre part, l'effet de la dette convertible reste limité à une influence positive sur le nombre de citations reçues. Par la suite, nous restreignons nos travaux aux cas où l'entreprise fait face à un endettement élevé, d'une part, et à des difficultés opérationnelles, d'autre part. Bien que l'innovation puisse être un moyen d'améliorer la situation de ces entreprises, ces dernières sont confrontées à des comportements d'aversion au risque de la part des créanciers et des objectifs divergents entre les actionnaires et créanciers. Dans le cas où l'entreprise fait face à un ratio d'endettement financier élevé nous remarquons que les dettes obligataire et convertible ne favorisent pas la prise de risque et donc l'innovation. Cependant, si l'entreprise fait face à des difficultés opérationnelles, nos résultats montrent l'influence positive de la dette convertible sur le nombre

de citations reçues uniquement. Le financement par dette convertible permet alors à l'entreprise d'entreprendre des projets d'innovation de meilleure qualité sans augmenter le volume de ces projets et donc le risque pris par l'entreprise. Il semble alors que la présence de dette convertible limite les incitations des actionnaires à la prise de risque excessive pouvant avoir pour conséquence la baisse de la valeur de l'entreprise et donc des créanciers.

L'ensemble de ces chapitres démontre la présence de mécanismes de gouvernement d'entreprise pouvant influencer les politiques d'innovation. Cette thèse contribue à la littérature académique de plusieurs manières. D'un point de vue méthodologique nous avons utilisé des modèles statistiques permettant d'identifier les processus d'innovation (chapitre 1), intégrant l'ensemble des dimensions du rôle du conseil d'administration (chapitre 2) et des situations particulières de difficultés financière et opérationnelle. Dès lors, nos contributions analytiques peuvent être synthétisées de la manière suivante : analyse du processus d'innovation plutôt que son succès, établissement d'une hiérarchie de l'influence des caractéristiques du conseil d'administration ainsi que de la structure de dette. Enfin, nos recherches permettent d'approfondir le débat sur le rôle du gouvernement d'entreprise dans l'innovation grâce aux résultats énoncés précédemment.

Ces travaux ont cependant des limites qu'il est nécessaire de souligner. En particulier, les mesures de l'innovation utilisées dans cette thèse (nombre de brevets et de citations reçues et, dans une moindre mesure, les dépenses en recherche et développement) peuvent faire l'objet de plusieurs critiques. Premièrement, les brevets concernent uniquement les inventions, procédés ou produits techniques. Dès lors, certains types d'innovation (organisationnelle, sociétale, etc.) ainsi que certains secteurs de l'économie sont mal représentés dans nos échantillons. Deuxièmement, puisque le dépôt de brevet implique de rendre publique l'invention, certaines entreprises peuvent faire le choix de garder secrètes certaines inventions pour des raisons stratégiques. Dès lors, ces inventions n'apparaissent pas dans nos échantillons. Enfin, le dépôt de brevet peut être l'objet d'une stratégie autre que la simple protection intellectuelle. Certaines entreprises déposent des brevets dans l'unique but de bloquer la concurrence dans des champs de connaissance pouvant faire l'objet de développements futurs. Concernant la recherche et développement, bien que la publication des montants dépensés soit obligatoire aux Etats-Unis, ce poste peut faire l'objet de manipulations comptables. Certaines entreprises peuvent intentionnellement cacher leur effort de R&D sans pour autant réduire le développement d'innovations. Une nouvelle fois, une partie des entreprises pouvant faire l'objet d'étude n'est simplement pas intégrée dans nos échantillons.

Les chapitres composant cette thèse peuvent faire l'objet d'approfondissement. Dans le cadre du premier chapitre une piste d'approfondissement concerne la méthode de classification des investisseurs institutionnels. Celle-ci est effectuée à partir de la société de gestion et non à partir du fonds. Les investisseurs institutionnels gèrent souvent un nombre conséquent de fonds dont les stratégies d'investissements et de gestion peuvent être différentes : certains sont dit indiciels (et prennent des participations dans les sociétés faisant partie de l'indice suivi), d'autres sont plus actifs dans la gestion de leur portefeuille. Notre étude pourrait être étendue en utilisant une classification des investisseurs à partir de leur fonds, jugée plus fine qu'une classification à partir de la société de gestion. Dans le cadre du second chapitre nous analysons uniquement les variables mesurant le résultat de l'innovation (brevets et citations). Une perspective de recherche future réside dans l'analyse des dépenses en recherche et développement, considérées comme la matière première de la politique d'innovation. Enfin le troisième chapitre de cette thèse pourrait se concentrer sur l'étude des mécanismes à l'origine de l'influence de la dette convertible et s'appuyer sur une définition plus précise des entreprises faisant face à des situations de conflits entre actionnaires et créanciers.

Cette thèse propose aussi quelques implications pour la sphère professionnelle. Elle permet de mettre en évidence que le succès d'un projet d'innovation n'est pas uniquement limité au montant investi, ni à la qualité des individus travaillant au sein de la division R&D. Cette thèse permet d'illustrer que l'innovation est fonction de plusieurs déterminants et qu'elle est le résultat d'un véritable système de relations internes à l'entreprise. Dès lors, les décisionnaires de l'entreprise doivent prendre en compte la dimension actionnariale, le conseil d'administration et les conflits créanciers-actionnaires dans l'élaboration de projets d'innovation.

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RÉSUMÉ

Notre compréhension des déterminants de l'innovation reste limitée, laissant place à un champ de recherche prolifique. Cette thèse se propose d'étudier les déterminants internes à l'entreprise dans la mesure où celle-ci est le principal lieu où l'innovation émerge. Nous étudions notamment, les mécanismes de gouvernement d'entreprise et mettons en évidence leur rôle dans la mise en place de politiques d'innovation. Notre recherche démontre l'influence positive des investisseurs institutionnels sur l'ouverture de structures de capital-risque d'entreprise, synonyme de processus d'innovation ouverte. Par ailleurs, nous démontrons que la composition du conseil d'administration favorise l'innovation grâce au réseau et à l'expertise sectorielle des administrateurs. Enfin, nous établissons une relation positive sur l'innovation du financement par dette obligataire et convertible.

MOTS CLÉS

Gouvernement d'entreprise, innovation, investisseurs institutionnels, conseil d'administration, structure de capital

ABSTRACT

Our understanding of the determinants of innovation remain limited, leaving place to a prolific field of study. This thesis provides a study of determinants internal to the firm, as it is the place where most innovations are produced. More precisely, we study the governance mechanisms at place between the different stakeholders of the firm. Our research shed light on the positive role of institutional investors in the opening of corporate venture capital structures, synonym of an open innovation process. Furthermore, we provide evidence that the board of directors affects corporate innovation thanks to directors' network and industrial expertise. Last, we demonstrate that the financing through bonds and convertible debt enhance the innovation output of a firm.

KEYWORDS

Corporate governance, innovation, institutional investors, board of directors, capital structure

