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INNOVATION ECOSYSTEMS: COMPLEMENTARY, SUBSTITUTIVE RELATIONS AND VALUE CREATION

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A mi familia

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Concluyo asumiendo toda la responsabilidad de los errores que puedan aparecer en las páginas siguientes de esta tesis doctoral.

RESUMEN BREVE

La innovación empresarial es considerada un fenómeno crucial para el crecimiento económico, el aumento de la productividad y la creación de empleo. Sin embargo, a pesar de ser considerara uno de los fenómenos clave de la vida económica, cómo se produce, cuáles son las relacionas que la desencadenan y de qué forma se puede potenciar es algo que sigue en discusión entre académicos, directivos y legisladores. Esta tesis doctoral tiene como objetivo responder a estas preguntas analizando la existencia de relaciones complementarias y sustitutivas entre los principales agentes del ecosistema innovador: socios científicos, socios de la cadena de suministro y empresas. Para ello, se proponen tres investigaciones:

La primera consiste en conectar la literatura sobre ecosistema de innovación con la de los sistemas de innovación. Estas dos comunidades han crecido de manera independiente y en los últimos años incluso enfrentadas. A través de un análisis bibliométrico se ofrece una síntesis que propone una agenda futura en tres temas clave para el análisis de la innovación como la creación de valor, los objetivos medioambientales y la gobernanza de los ecosistemas de innovación.

La segunda investigación aborda la creación de valor entre socios científicos y empresas desde una nueva perspectiva. A través de un análisis de metaregresión de los trabajos previamente publicados se mide el efecto real de esta relación teniendo en cuenta el sesgo de publicación y la heterogeneidad de cada estudio. Esta investigación permite conocer los determinantes de la creación de valor entre ambos agentes y su impacto real.

La tercera aborda las relaciones complementarias y sustitutivas entre socios científicos, de la cadena de suministro y empresas en la introducción de innovaciones con objetivos medioambientales. De esta investigación se concluye cuáles son las combinaciones de distintos agentes que aumentan la probabilidad de introducir este tipo de innovaciones y cuáles son aquellas que producen efectos negativos.

Finalmente, con esta tesis se pretenden sentar las bases teóricas para futuras investigaciones que tengan en cuenta a otros agentes cruciales del ecosistema innovador como gobiernos, emprendedores y al capital riesgo.

ABSTRACT

Firm innovation is considered crucial for economic growth, productivity and job creation. However, despite being considered one of the key phenomena of economic life, how it occurs, what relationships trigger it and how it can be promoted are still under discussion among academics, managers and policymakers. This doctoral dissertation aims to clarify these questions by analysing the existence of complementary and substitutive relationships between the primary agents of the innovative ecosystem: scientific, supply chain partners and firms. To achieve this goal, three analyses were carried out:

The first analysis connects the literature on the innovation ecosystem with that on innovation systems. These two communities have grown independently and, in recent years, have even clashed. Using a bibliometric analysis, this research offers a synthesis with which a future agenda on three key topics for the analysis of innovation such as value creation, environmental objectives and governance of the environment can be proposed.

The second research analyses value creation between scientific partners and companies from a new perspective. Using a meta-regression analysis of previously published works, this research computes the real effect of this relationship, taking into account publication bias and the heterogeneity of each study. This research informs us of what the determinants of value creation between agents are and draws important conclusions for the future.

The third research focuses on the complementary and substitutive relationships between scientific, supply chain partners and focal firms in order to introduce innovations with environmental objectives. From this research, it is concluded which the combinations of different agents are that increase the probability of introducing this crucial type of innovation and which produce adverse effects.

Finally, this doctoral dissertation intends to lay the theoretical foundations for future research which considers other crucial agents of the innovative ecosystem, such as governments, entrepreneurs and venture capital.

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CAPÍTULO 1. INTRODUCCIÓN

Durante más de un siglo, la innovación empresarial ha sido considerada un elemento clave para el crecimiento económico de los países, como escribió Schumpeter (1939, p. 83): "no hay nada más claro que la innovación es el centro de prácticamente todos los fenómenos de la [...] vida económica". Desde entonces, economistas e investigadores han tratado de cuantificar los efectos positivos generados por este proceso en diversas variables como el crecimiento económico (Howitt & Aghion, 1998), la creación de empleo (Freeman, 1982) o la productividad (David, 1990) contribuyendo a crear un amplio consenso sobre los beneficios de la innovación (Aghion et al., 2021). Sin embargo, el proceso por el cual se produce la innovación, los agentes que intervienen y de qué forma se pueden incrementar sus resultados es algo que sigue en discusión entre directivos, académicos y legisladores.

Los estudios sobre innovación y en concreto, aquellos relacionados con los "sistemas de innovación" han tratado de responder a estas y otras cuestiones proponiendo modelos universales con los que explicar el fenómeno y sus resultados. El principal modelo ha sido el de Sistemas Nacionales de Innovación (Lundvall, 1992), seguido por sus diversas adaptaciones como el Sistema Regional de Innovación (Asheim & Coenen, 2005) o los Modelos de Triple Hélice (Etzkowitz & Leydesdorff, 2000) y más recientemente por los Sistemas Nacionales de Emprendimiento (Ács et al., 2014). De esta forma, los investigadores han enriquecido mucho la comprensión sobre el proceso innovador, su desarrollo a diferentes niveles y el rol jugado por los distintos agentes. Sin embargo, esta amplia variedad de perspectivas y marcos teóricos ha introducido una excesiva complejidad que es difícil de descifrar por los legos en la materia (Rakas & Hain, 2019).

Es por ello que, durante la última década, el enfoque del "ecosistema innovador" ha ganado mucha popularidad entre empresas (Judah et al., 2020), universidades (Feldman et al., 2019; Beaudry et al., 2021) y gobiernos (European Commission, 2021). Con raíces en la estrategia empresarial, este marco teórico se centra en las relaciones colaborativas y competitivas a través de las cuales las empresas combinan sus recursos internos con otros recursos de socios externos con el objetivo de resolver demandas del mercado y crear valor a través de la innovación (Adner, 2006; Adner, 2012). Y, aunque el concepto de ecosistema innovador es emergente y está todavía en discusión (Autio & Thomas, 2022), una de las definiciones más utilizadas para referirse a él es la propuesta por Granstrand y Holgersson (2020, p. 3) quienes lo describen como:

> "El conjunto en evolución de actores, actividades, artefactos, instituciones y relaciones, incluidas las relaciones complementarias y sustitutivas, que son importantes para el desempeño innovador de un actor o una población de actores".

Desde esta perspectiva, esta tesis doctoral tiene como objetivo analizar la existencia de relaciones complementarias y sustitutivas entre los principales actores del ecosistema de innovación. Obviamente, este trabajo no pretende analizar todas las combinaciones posibles -eso sería un trabajo para una vida o varias- sino analizar las interacciones entre empresas, socios científicos y socios de la cadena de suministro. De esta forma, este enfoque proporcionará una perspectiva panorámica de lo que se puede esperar de la interacción con los principales actores externos y sentará las bases necesarias para estudios futuros que incluirán a más actores clave.

Finalmente, este capítulo introductorio proporciona al lector un resumen sobre los temas tratados y las principales preguntas que serán analizadas con mayor profundidad a lo largo de los siguientes capítulos.

1.1. ¿Por qué es relevante la perspectiva del ecosistema innovador?

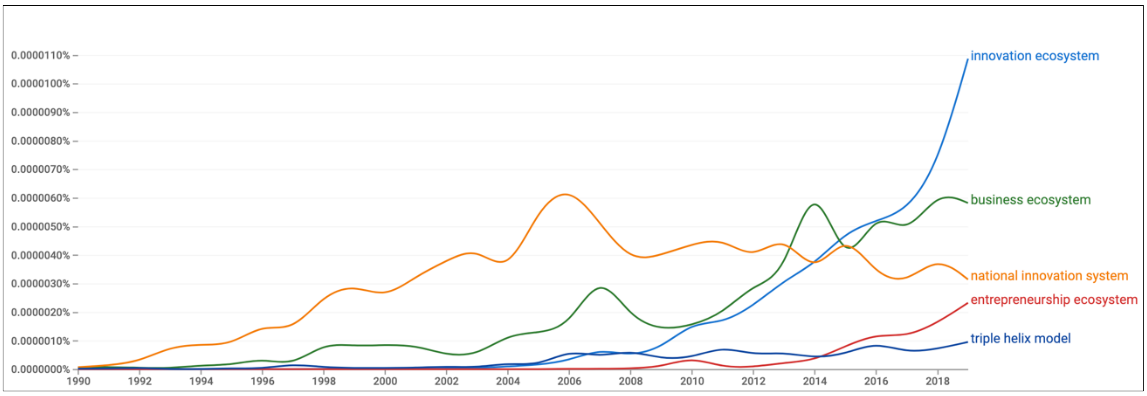
El concepto de ecosistema innovador se fundamenta en que la innovación es un proceso interactivo en el que actores autónomos combinan sus recursos para perseguir objetivos alineados y crear valor (Adner, 2006; Jacobides et al., 2018, p. 2263). Estudios previos sobre innovación han demostrado que la colaboración de las empresas con clientes (Von Hippel, 1978; Liao & Tsai, 2019), con proveedores (Ragatz et al., 1996; Kobarg et al., 2020) y con socios científicos (Perkmann & Walsh, 2007; Mothe et al., 2018) mejora el desempeño innovador de las empresas, lo que se traduce en crecimiento económico para ellas y para la sociedad (Autio & Thomas, 2022).

Sin embargo, las interacciones entre los diferentes actores no surgen espontáneamente, sino que son el resultado de decisiones deliberadas. De esta forma, una empresa puede optar por colaborar con un proveedor para introducir una innovación de proceso, con una universidad para absorber conocimiento científico o con ambos para tratar de combinar sus diferentes recursos a la vez. Estas decisiones se presuponen racionales y se basan en la existencia de metas alineadas entre los distintos agentes (Granstrand & Holgersson, 2020). Pero como la literatura sobre empresa ha demostrado, las decisiones estratégicas no siempre son racionales y es por ello que es crucial ofrecer información sobre los resultados que cada interacción va a tener sobre la innovación de la empresa (Eisenhardt & Zbaracki, 1992).

Además, desde esta perspectiva, la innovación es vista como un proceso interactivo en el que los actores no pueden ser controlados jerárquicamente y ninguno de ellos por sí solo podría impulsar la innovación (Lerner, 2012). De esta forma, son considerados agentes autónomos que interactúan para buscar su beneficio individual innovando y de esta forma generar externalidades positivas para el entorno (Adner, 2012). La metáfora del “ecosistema” hace referencia también a los efectos simbióticos que las interacciones entre los diferentes agentes podrían producir: “beneficio mutuo” (relaciones complementarias) o “daño mutuo” (relaciones sustitutivas). El primero considera que los agentes tienen realmente objetivos alineados y que la interacción los beneficia a todos (Belderbos et al., 2004; Adner, 2012). El segundo que, aunque ambos agentes decidan colaborar, en realidad no tienen metas alineadas y, por tanto, su relación produce efectos adversos para ambos (Laursen & Salter, 2006; Jacobides et al., 2018). La sencillez con la que la metáfora del “ecosistema” transmite esta información ha contribuido a la rápida difusión del concepto de ecosistema innovador.

La difusión de este concepto se puede medir utilizando herramientas de minería de texto como Google Ngram Viewer. Esta herramienta gratuitita analiza el número de veces que aparece un término en un corpus de libros (Bone & Rotolo, 2019; Younes & Reips, 2019). De esta forma, analizando todos los libros en inglés publicados entre 1990 y 2019 se puede comparar la evolución del término en relación a otros. La Figura 1.1 muestra la evolución del término ecosistema innovador (innovation ecosystem) y de otros como ecosistema empresarial (business ecosystem), sistema nacional de innovación (national innovation system), de emprendimiento (national entrepreneurship system) o modelo de triple hélice (Triple helix model). Como se puede observar, el rápido crecimiento del término ecosistema de innovación desde mediados de la década pasada revela cómo la metáfora del "ecosistema" ha sido asimilada rápidamente por la sociedad como la forma útil para comprender el proceso innovador (Judah et al., 2020).

Figura 1.1. Difusión del concepto de ecosistema de innovación frente a otros



Fuente: Elaboración propia

Finalmente, aunque el término proviene de los estudios de dirección de empresas (Adner, 2006; Adner & Kapoor, 2010), la gran adopción de este concepto por todos los agentes sociales ofrece la oportunidad de transferir el conocimiento producido por marcos teóricos previos (Feldman et al., 2019). Además, su orientación a analizar las relaciones entre los agentes como no jerárquicamente organizadas proporciona una perspectiva más realista de cómo se produce la innovación y lo difícil que es tratar de dirigir este fenómeno en entornos complejos (Lerner, 2012; European Commission, 2021).

1.2. ¿Cuáles son los principales actores del ecosistema innovador?

El ecosistema innovador supera marcos teóricos previos para reflejar la realidad de la innovación en el siglo XXI (Nambisan & Baron, 2013). En lugar de centrarse en actores específicos como hicieron los modelos de triple hélice o de cerrarse a contextos específicos como hicieron los modelos nacionales o regionales. La perspectiva del ecosistema innovador permite analizar a todos los agentes que participan en el proceso de innovación con flexibilidad espacial (Arora et al., 2019; Feldman et al., 2019). En ciertos ecosistemas, estas relaciones pueden implicar conexiones globales mientras que en otros pueden ser a nivel de clúster, región o país (Autio & Thomas, 2022). Además, los agentes que participen pueden variar en función del contexto, pero como señalan Budden y Murray (2019) siempre se pueden encontrar los siguientes agentes:

Empresas: Las empresas tienen los recursos, las estructuras organizacionales y capacidades dinámicas necesarias para combinar con éxito el conocimiento interno y externo para desarrollar innovaciones y crear valor (Adner, 2012). Además, debido a su orientación a las necesidades del mercado, los directivos están orientados a elaborar modelos de negocios basados en las necesidades sociales (Moore, 1996; Nambisan & Baron, 2013).

Socios científicos: Durante las últimas décadas, los académicos han estudiado el papel que juegan las universidades en el desarrollo de algunos de los ecosistemas de innovación más poderosos como Silicon Valley o Great Boston (Saxenian, 1996; Taylor, 2016) y si bien son las universidades el agente científico más icónico, esta categoría también incluye a todos los socios científicos que aportan nuevos conocimientos a la sociedad, como institutos de investigación o laboratorios privados de I+D (Adams et al., 2003; Vivas & Barge-Gil, 2015). De esta forma, las universidades y el resto de socios científicos juegan un papel crucial en el desarrollo de nuevas tecnologías, infraestructuras científicas, spinoffs, nuevos conocimientos y formación de personal científico (Sánchez-Barrioluengo, 2014).

Socios de la cadena de suministro: Los proveedores y clientes de bienes y servicios juegan un papel crucial en el desempeño de la innovación (Delgado & Mills, 2020). Ellos producen inputs especializados que pueden hacer más eficiente el proceso de innovación (Rosenberg & Nelson, 1994). Como diversos autores han señalado, las innovaciones desarrolladas por los proveedores pueden difundirse más ampliamente a otras industrias (Bresnahan & Trajtenberg, 1995).

De esta forma, se generan externalidades positivas que contribuyen a la innovación y el crecimiento (Porter, 1998; Delgado et al., 2016).

Gobiernos: La existencia de fallos de mercado hace que la participación del gobierno en el ecosistema de innovación sea importante (Nelson & Winter, 1982). Los gobiernos deben participar en el proceso de innovación, proporcionando fondos y construyendo infraestructuras necesarias para que los agentes privados puedan innovar (Chaminade et al., 2018). Aunque desde la perspectiva de los ecosistemas de innovación, los gobiernos no han sido ampliamente considerados como agentes cruciales, su presencia es fundamental para dar forma a reglas, normas y programas de apoyo a la I+D (Borrás & Edquist, 2013; Arora et al., 2019).

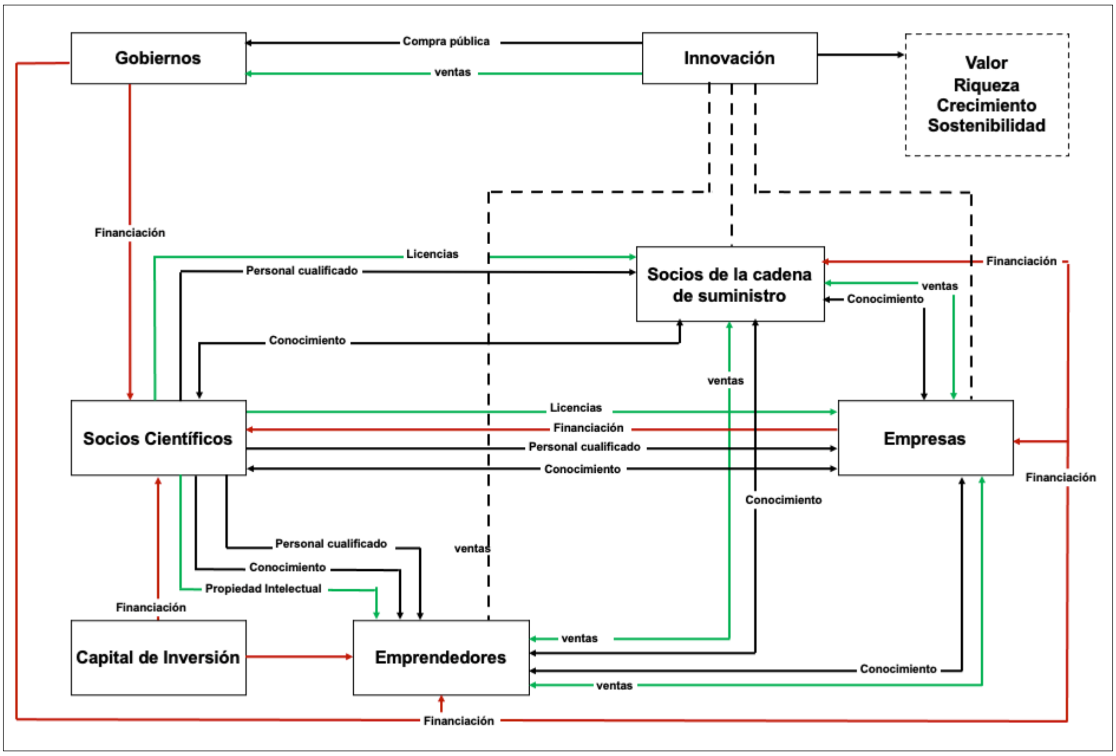
Emprendedores: El emprendimiento es un fenómeno crucial en el ecosistema de innovación (Ács et al., 2014). A diferencia de otros tipos de empresas como las pequeñas y medianas empresas (PYMES) o las empresas locales (Delgado & Mills, 2020), las startup-ups se fundan con la intención explícita de construir una ventaja competitiva basada en nuevas modelos de negocios para aumentar y escalar la creación de valor más allá de los mercados locales. De esta forma, las startups aspiran a un crecimiento significativo que repercuta en un beneficio positivo para toda la sociedad (Budden & Murray, 2019).

Capital riesgo: En los ecosistemas de innovación más financiarizados, los fondos de capital riesgo proporcionan recursos cruciales para promover el espíritu empresarial (Ács & Audretsch, 2005). En la Unión Europea, estos actores aún se encuentran en una fase temprana de desarrollo (Bosma et al., 2018). Sin embargo, en el futuro van a jugar un papel crucial para superar la “paradoja europea”, que consiste en ser líderes en la producción de conocimiento científico, y no ser capaces de comercializarlo a través de nuevas empresas (Fragkandreas, 2017).

La Figura 1.2 muestra a estos actores y las relaciones que se pueden establecer entre ellos de una forma esquemática (Georghiou, 2015). La flexibilidad del concepto de ecosistema de innovación permite adaptar el análisis a cada tipo de contexto en el que la interacción entre los agentes puede variar. Por ejemplo, en algunos ecosistemas de innovación como la Ruta 128 (Boston) o Silicon Valley

(San Francisco), el papel jugado por las universidades como el Massachusetts Institute of Technology o Stanford University fue crucial para el desarrollo del ecosistema de innovación (Saxenian, 1996). En otros países como Japón, el gobierno central desempeñó un papel crucial en la orientación de las empresas para desarrollar innovaciones e invertir en actividades de I+D (Freeman, 1987). En Israel, el capital riesgo y las startups jugaron un papel más importante para desarrollar uno de los ecosistemas de innovación más dinámicos de todo Oriente Medio y el Mar Mediterráneo (Brown & Mason, 2017).

Figura 1.2. Relaciones entre los principales agentes del ecosistema innovador



Fuente: Adaptado de Georghiou (2015)

1.3. ¿Por qué analizar las relaciones complementarias y sustitutivas?

La metáfora del ecosistema introduce la interacción entre diferentes organismos y cómo las relaciones pueden producir dos situaciones extremas: beneficio mutuo (relaciones complementarias) o daño mutuo (relaciones sustitutivas) (Oh et al., 2016; Granstrand & Holgersson, 2020).

Por un lado, las relaciones complementarias suponen que aumenten los resultados para ambos agentes en términos de innovación, pero también en términos de creación de valor. La generación de riqueza y crecimiento para los agentes repercute de manera positiva para el resto de agentes del ecosistema y para la sociedad en su conjunto (Thomas & Autio, 2020). Además, durante los últimos años las innovaciones se introducen teniendo en cuenta objetivos de sostenibilidad, lo que beneficia aún más a la sociedad reduciendo el impacto medioambiental de la introducción de nuevos productos o procesos (De Marchi, 2012).

Por otro, las tensiones entre actores pueden detener la acción colectiva y producir resultados decrecientes (Budden & Murray, 2019, p. 28; Granstrand & Holgersson, 2020, p. 5). Estos resultados negativos no solo se producen cuando los actores compiten entre sí, sino que también cuando los actores cooperan (Ritala et al., 2013, p. 3). Este efecto no deseado puede ser causado por el mecanismo utilizado, la no correcta alineación de los objetivos, o la existencia de barreras en la colaboración (Normann & Ramirez, 1993).

Analizar y comprender qué relaciones tienen más probabilidades de aumentar la innovación y cuales podrían conducir a resultados negativos es fundamental para que los directivos y los encargados de formular políticas públicas tomen las decisiones correctas (Funk, 2009). Algunas de las relaciones complejas que son particularmente comunes y requieren profundizar en su análisis son las siguientes:

Relaciones entre socios científicos, socios de la cadena de suministro y empresas: la colaboración con socios externos es un determinante crítico para la innovación y la creación de valor de las empresas (Haus-Reve et al., 2019). Hoy en día, cada vez son más los agentes que colaboran para desarrollar innovaciones que generen valor tanto para las empresas como para la sociedad siguiendo estrategias de colaboración. Las principales interacciones se producen con socios científicos y de la cadena de suministro (Del Río et al., 2016). Cada socio externo ofrece acceso a diferentes recursos clave para la innovación de las empresas; y si bien, varios académicos han afirmado que múltiples acuerdos de colaboración pueden generar efectos complementarios y aumentar la probabilidad de innovación de las empresas (De Marchi, 2012), otros han señalado que a medida que aumenta el número de socios externos se producen tensiones entre ellos

(Kobarg et al., 2020). Las tensiones entre estos tres agentes podrían producir que la combinación de diferentes socios externos produzca un efecto sustitutivo en innovaciones cruciales para las empresas y la sociedad.

Relaciones entre distintos gobiernos y empresas: Estudios previos han analizado el impacto de programas gubernamentales específicos para el fomento. Sin embargo, la existencia de efectos de complementariedad entre diferentes programas públicos ha sido poco analizada (Czarnitzki & Lopes-Bento, 2014; Huergo & Moreno, 2017). Sin embargo, dado que la mayoría de estos programas se han implantado en estados con un diseño de gobernanza multinivel, donde las instituciones regionales, nacionales y supranacionales deben alinear sus objetivos, resulta crucial analizar los efectos complementarios (Mulligan et al., 2019). La interacción entre las distintas ayudas puede producir un aumento en la innovación de las empresas si tienen objetivos alineados o un efecto negativo si persiguen objetivos opuestos o no alineados (Flanagan et al., 2011).

Relaciones entre gobiernos, capital riesgo y emprendedores: Los emprendedores y las startups juegan un papel clave a la hora de crear innovaciones radicales. Sin embargo, las limitaciones financieras que sufren muchas veces imposibilitan la puesta en marcha de estos nuevos modelos de negocios. Fondos públicos como los préstamos participativos respaldados por el gobierno son instrumentos híbridos que presentan características de préstamos y acciones que permiten a las empresas acceder a fondos sin perder la propiedad. A pesar de su creciente relevancia, solo Martí & Quas (2016) y Bertoni et al. (2019) han aportado evidencia científica sobre su impacto que evalúa el efecto de esta herramienta de financiación. El primero mostró el efecto positivo de los préstamos participativos como una señal para los inversores privados, y el segundo encontró efectos de crecimiento sustanciales en las empresas emprendedoras jóvenes con respecto al empleo y las ventas. Sin embargo, no existe ningún trabajo que analice la existencia de complementariedad entre estas ayudas y el capital riesgo sobre la innovación de estas empresas y su impacto en la creación de nuevos modelos de negocio.

1.4. Objetivos específicos y estructura de esta tesis

1.4.1. Objetivos específicos

Como hemos dicho antes, esta tesis doctoral tiene como objetivo analizar las relaciones complementarias y sustitutivas entre los principales actores de los ecosistemas de innovación. Analizarlas todas sería un trabajo de una o de varias vidas por lo que en esta tesis doctoral nos centraremos en las relaciones entre **socios científicos, de la cadena de suministro y empresas**. Para analizar estas relaciones, nos planteamos tres objetivos de investigación específicos alineados con la construcción de un marco teórico de investigación y el análisis de las relaciones complementarias y sustitutivas:

El **primer objetivo específico** de investigación de esta tesis doctoral es analizar la evolución de la literatura sobre ecosistemas de innovación tratando de conectarla con la literatura previa sobre sistemas de innovación. Debido a la popularización del concepto de ecosistema de innovación entre académicos, empresas y legisladores se requiere avanzar en el debate y enriquecer el concepto con lo que han teorizado corrientes previas. Nuestro objetivo es encontrar las complementariedades entre ambas literaturas y ser capaces de ofrecer una agenda conjunta de investigación para que los estudios sobre innovación consigan avanzar en el futuro lejos de etiquetas y de vetos cruzados.

El **segundo objetivo específico** es estudiar las relaciones entre empresas y socios científicos, sus tipos y su impacto en el rendimiento económico e innovador. La literatura sobre innovación ha determinado que la colaboración Universidad-Industria es una de las relaciones críticas del ecosistema innovador. Además, señala que estas relaciones aumentan la innovación técnica de las empresas (patentes, nuevos conocimientos) que se traduce en desempeño económico (facturación del proceso innovador, desempeño económico, productividad). Pero, ¿es esto verdad? ¿Todos los tipos de relaciones universidad-industria producen efectos positivos? Nuestro objetivo es medir el impacto real de estas relaciones, considerando el tipo de socio científico, el mecanismo elegido y el resultado analizado.

El **tercer objetivo específico** de investigación de esta tesis doctoral es estudiar las relaciones entre los socios científicos, socios de la cadena de suministro y las empresas innovadoras. La colaboración con diferentes socios se ha señalado como un proceso clave para impulsar la innovación de las empresas. Tradicionalmente la literatura que ha analizado este mecanismo se ha centrado en socios individuales o en el número de socios, pero ha omitido la combinación de diferentes tipos de socios y los efectos complementarios o sustitutivos que se producen entre ellos. Nuestro objetivo es medir la existencia de relaciones complementarias y sustitutivas entre socios científicos y clientes y proveedores capaces de aumentar la probabilidad de que las empresas introduzcan innovaciones clave para toda la sociedad.

1.4.2. Estructura de la tesis

1.4.2.1. Cerrando la brecha entre los ecosistemas de innovación y los sistemas de innovación: Una revisión bibliométrica

El Capítulo 2 investiga la evolución de la literatura sobre ecosistemas de innovación y sistemas de innovación y la existencia de complementariedades entre ambas comunidades científicas para ofrecer un marco teórico en el que puedan sustentarse las siguientes investigaciones. Si bien durante la última década ha habido un intenso debate sobre la metáfora del "ecosistema", la popularización del concepto de “ecosistema innovador” entre académicos, empresas y gobiernos requiere avanzar en el debate y enriquecer el concepto con lo que ambas literaturas sobre innovación han descubierto durante las últimas cuatro décadas.

Para lograr este objetivo, analizamos 6.500 documentos científicos publicados entre 1975 y 2021 relacionados con los sistemas y ecosistemas de innovación mediante un análisis bibliométrico. Específicamente, nos basamos en el análisis de impacto y el mapeo científico para extraer las publicaciones, los temas y las citas más importantes. Nuestros hallazgos revelan que tres temas principales pueden cerrar la brecha entre ambas literaturas: i) Gobernanza y problemas de legitimidad, ii) innovaciones ambientales, y iii) co-creación y apropiación de valor. Los resultados de este trabajo ayudan a académicos, directivos y gobiernos a descubrir las diferencias y similitudes entre ambos conceptos, así como a establecer un marco común para desarrollar una agenda de investigación conjunta.

1.4.2.2. El impacto de las relaciones entre la universidad y la industria en el desempeño de las empresas: Un análisis de metaregresión

El Capítulo 3 se centra en las relaciones de complementariedad entre los socios científicos y las empresas. Durante el último cuarto de siglo, se ha dado una amplia difusión de recursos públicos para promover esta relación y un gran número de estudios ha evaluado sus resultados. Sin embargo, mientras que la teoría de la innovación identifica esta relación como un instrumento claramente positivo para aumentar el desempeño de las empresas, la literatura empírica ha reportado una amplia variedad de resultados tanto positivos como negativos.

Para superar este conflicto entre la teoría y los resultados observados, llevamos a cabo un análisis de meta regresión, basado en 51 estudios y 173 estimaciones del impacto a nivel de empresa publicadas desde 1995. Después de controlar el sesgo de publicación, la muestra y las heterogeneidades de cada estudio, nuestros resultados muestran que la relación universidad-empresa solo produce un pequeño efecto en el desempeño de las empresas. Además, descubrimos, que este efecto es más significativo para los resultados técnicos que para los resultados económicos. A través de este análisis descubrimos cuáles son los determinantes asociados con los resultados positivos y exploramos algunas recomendaciones que las empresas, los académicos y los gobiernos pueden aplicar para mejorar los resultados de innovación a la hora de colaborar con socios científicos.

1.4.2.3. Colaboración con los socios externos: Efectos complementarios y sustitutivos en la ecoinnovación de las empresas

El Capítulo 4 investiga si los acuerdos de colaboración con diferentes tipos de socios externos producen efectos complementarios sobre la probabilidad de introducir innovaciones con objetivos medioambientales. Aunque las teorías sobre colaboración externa e innovación abierta afirman que la combinación de socios externos, como socios científicos, proveedores y clientes, produce efectos complementarios sobre este tipo de innovaciones, otros han encontraron la existencia de efectos sustitutivos.

Para resolver este conflicto, modelamos la naturaleza de la interacción entre diferentes socios externos, analizando una muestra de panel no balanceada de 10.918 empresas españolas innovadoras durante el período 2008-2016. Nuestros resultados muestran que las empresas que colaboran simultáneamente con socios científicos, proveedores y clientes obtienen efectos complementarios parciales que aumentan la probabilidad de la empresa de ecoinnovar más que ninguna otra combinación de socios externos. Por otra parte también se encontró que la colaboración de clientes con socios científicos, o colaboración de proveedores, produce efectos sustitutivos parciales.

1.4.2.4. Discusión general

Finalmente, en el Capítulo 5 se ofrecen los comentarios finales, destacando las principales implicaciones prácticas de los estudios de esta disertación para directivos, académicos y gobiernos, así como interesantes ideas para futuras investigaciones en los que se analiza el resto de relaciones complejas.

CHAPTER 1. INTRODUCTION

For more than a century, innovation has been considered an essential element for the economic growth of countries; as Schumpeter (1939, p. 83) wrote: "there is nothing more clear than innovation is the centre of practically all phenomena of [...] economic life". Since then, economists and researchers have tried to quantify the positive effects generated by this process on various variables such as economic growth (Howitt & Aghion, 1998), job creation (Freeman, 1982) and productivity (David, 1990). These studies help to create a broad consensus on the benefits of innovation (Aghion et al., 2021). However, the process by which innovation occurs, the agents involved and its results can be increased is still under discussion among practitioners, scholars and policymakers.

Innovation studies and, specifically, those related to "innovation systems" have tried to answer these and other questions by proposing universal models to explain the innovation phenomenon and its results. The main model has been the National Innovation Systems (Lundvall, 1992), followed by its various adaptations, such as the Regional Innovation Systems (Asheim & Coenen, 2005), the Triple Helix Models (Etzkowitz & Leydesdorff, 2000) and, recently, by the National Entrepreneurship Systems (Ács et al., 2014). These models have greatly enriched the understanding of the innovative process, its development at different levels and the role played by the different agents. However, this wide variety of perspectives and theoretical frameworks has introduced excessive complexity which is difficult for non-specialists to understand (Rakas & Hain, 2019).

That is why, during the last decade, the “innovation ecosystem” approach has gained much popularity among companies (Judah et al., 2020), universities (Beaudry et al., 2021; Feldman et al., 2019) and governments (European Commission, 2021). From business strategy, this theoretical framework focuses on collaborative and competitive relationships through which companies combine their internal resources with external partners to satisfy market demands and create value through innovation (Adner, 2006; Adner, 2012). Furthermore, although the concept of an innovation ecosystem is emerging and is still under discussion (Thomas & Autio, 2020), one of the most used definitions to refer to it is the one proposed by Grandstrand & Holgersson (2020, p. 3), who describe it as:

> "The evolving set of actors, activities, artefacts, institutions, and relationships, including complementary and substitute relationships, that are important to the innovative performance of an actor or a population of actors".

From this perspective, this doctoral dissertation aims to analyse the existence of complementary and substitutive relationships among the main actors in the innovation ecosystem. This work does not intend to analyse all the possible combinations –that would be a job for a lifetime or several– but to analyse the main interactions among the most important agents of the innovation ecosystem: firms, scientific and supply chain partners. This approach will provide a panoramic perspective of what can be expected from the interaction with the main external actors and will lay the necessary foundations for future studies that include more key actors.

This introductory chapter provides the reader with a summary of the topics covered and the main questions that will be analysed in greater depth throughout the following chapters.

1.1. Why is the innovation ecosystem perspective relevant?

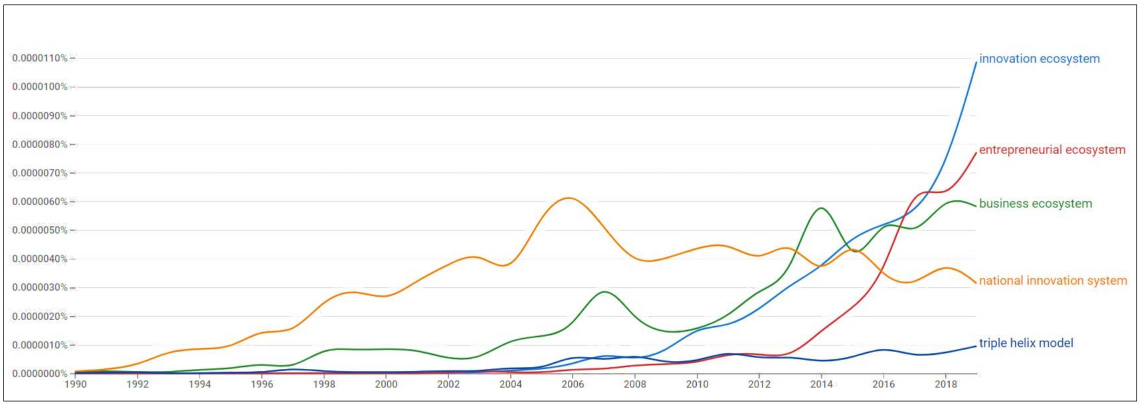
The innovation ecosystem concept is based on the fact that innovation is an interactive process in which autonomous actors combine their resources to pursue aligned objectives and create value (Adner, 2006; Jacobides et al., 2018, p. 2263). Previous studies on innovation have shown that the collaboration of firms with customers (Von Hippel, 1978; Liao & Tsai, 2019), suppliers (Ragatz et al., 1996; Kobarg et al., 2020) and scientific partners (Perkmann & Walsh, 2007; Mothe et al., 2018), improves the firm's innovation performance, which translates into economic growth for them and for society (Autio & Thomas, 2022).

However, the interactions among the different actors do not arise spontaneously but result from deliberate decisions. In this way, a company can collaborate with a supplier to introduce a process innovation, with a university to absorb scientific knowledge, or with both to combine their different resources simultaneously. These decisions are assumed to be rational and are based on the existence of aligned goals among the different agents (Granstrand & Holgersson, 2020). However, as the business literature has shown, strategic decisions are not always rational, so it is crucial to provide information regarding the results of each interaction on the firm's innovation (Eisenhardt & Zbaracki, 1992).

From this perspective, innovation is seen as an interactive process in which the actors cannot be hierarchically controlled, and none of them alone could drive innovation (Lerner, 2012). In this way, they are considered autonomous agents that interact to seek their benefit by innovating and thus generate positive externalities for the environment (Adner, 2012). The "ecosystem" metaphor refers to the effects that the interactions among the different agents could produce: "mutual benefit" (complementary relationships) or "mutual harm" (substitute relationships). The former considers that the agents have aligned goals and that the interaction benefits them all (Belderbos et al., 2004; Adner, 2012). The latter considers that although both agents decide to collaborate, they do not have aligned goals and, therefore, their relationship produces adverse effects for both (Laursen & Salter, 2006; Jacobides et al., 2018). The simplicity with which the "ecosystem" metaphor conveys this information has contributed to the rapid spread of the innovation ecosystem concept.

The spread of this concept can be measured using text-mining tools such as Google Ngram Viewer. This free tool analyses the number of times a term appears in a corpus of books (Bone & Rotolo, 2019; Younes & Reips, 2019). By analysing all the books in English published between 1990 and 2019, it is possible to compare the evolution of the term in relation to others. 0 shows the evolution of the term *innovation ecosystem* and others such as *business ecosystem*, *national innovation system*, *national entrepreneurship system* and *triple helix model*. As can be seen, the rapid growth of the term innovation ecosystem since the middle of the last decade reveals how the "ecosystem" metaphor has been quickly assimilated by society as a useful way to understand the innovative process (Judah et al., 2020).

Figure 1.1. Diffusion of the innovation ecosystem concept compared to others



Source: Own elaboration

Finally, although the term comes from business management studies (Adner, 2006; 2010), the wide adoption of this concept by all social agents offers the opportunity to transfer the knowledge produced by previous theoretical frameworks (Feldman et al., 2019). In addition, its orientation to analyse the relationships among agents as non-hierarchically organized provides a more realistic perspective of how innovation occurs and how difficult it is to manage this phenomenon in complex environments (Lerner, 2012; European Commission, 2021).

1.2. Which are the main actors in the innovation ecosystem?

The innovation ecosystem goes beyond previous theoretical frameworks to reflect the reality of innovation in the 21st century (Nambisan & Baron, 2013). Instead of focusing on specific actors or specific contexts, the perspective of the innovation ecosystem allows analysing all the agents that participate in the innovation process with spatial flexibility (Feldman et al., 2019; Arora et al., 2019). In certain ecosystems these relationships may involve global connections while in others they may be at the cluster, region or country level (Autio & Thomas, 2022). In addition, the agents that participate may vary depending on the context, but as Budden & Murray (2019) point out, the following agents can always be found:

Focal firms: They have the resources, organizational structures and dynamic capabilities necessary to successfully combine internal and external knowledge to develop innovations and create value (Adner, 2012). In addition, due to their orientation to market needs, managers are guided to develop business models based on social needs (Moore, 1996; Nambisan & Baron, 2013).

Scientific partners: During the last decades, academics have studied the role that universities play in the development of some of the most powerful innovation ecosystems, such as Silicon Valley and Great Boston (Saxenian, 1996; Taylor, 2016), and although they are the most iconic scientific agents, this category also includes all scientific partners that bring new knowledge to society, such as research institutes and private R&D laboratories (Adams et al., 2003; Vivas & Barge-Gil, 2015). In this way, universities and other scientific partners play a crucial role in developing new technologies, scientific infrastructures, spinoffs, new knowledge and in training scientific personnel (Sánchez-Barrioluengo, 2014).

Supply chain partners: Suppliers and customers of goods and services play a crucial role in innovation performance (Delgado & Mills, 2020). They produce specialized inputs to make innovation more efficient (Rosenberg & Nelson, 1994). As various authors have pointed out, innovations developed by suppliers can be more widely spread to other industries (Bresnahan & Trajtenberg, 1995) and positive externalities contribute to innovation and growth (Porter, 1998; Delgado et al., 2016).

Governments*:* The existence of market failures makes government participation in the innovation ecosystem important (Nelson & Winter, 1982). Governments must participate in the innovation process, providing funds and building the necessary infrastructure so private agents can innovate (Chaminade et al., 2018), although from the perspective of the innovation ecosystem, governments have not been widely considered crucial agents. However, their presence is essential to shaping rules, regulations and support programmes for R&D (Borrás & Edquist, 2013; Arora et al., 2019).

Entrepreneurs: Entrepreneurship is a crucial phenomenon in the innovation ecosystem (Ács et al., 2014). Unlike other types of companies, such as small and medium-sized enterprises (SMEs) or local companies (Delgado & Mills, 2020), startups are founded with the explicit intention of building a competitive advantage based on new business models for the increase and scale value creation beyond local markets. In this way, startups aspire to significant growth that positively impacts society (Budden & Murray, 2019).

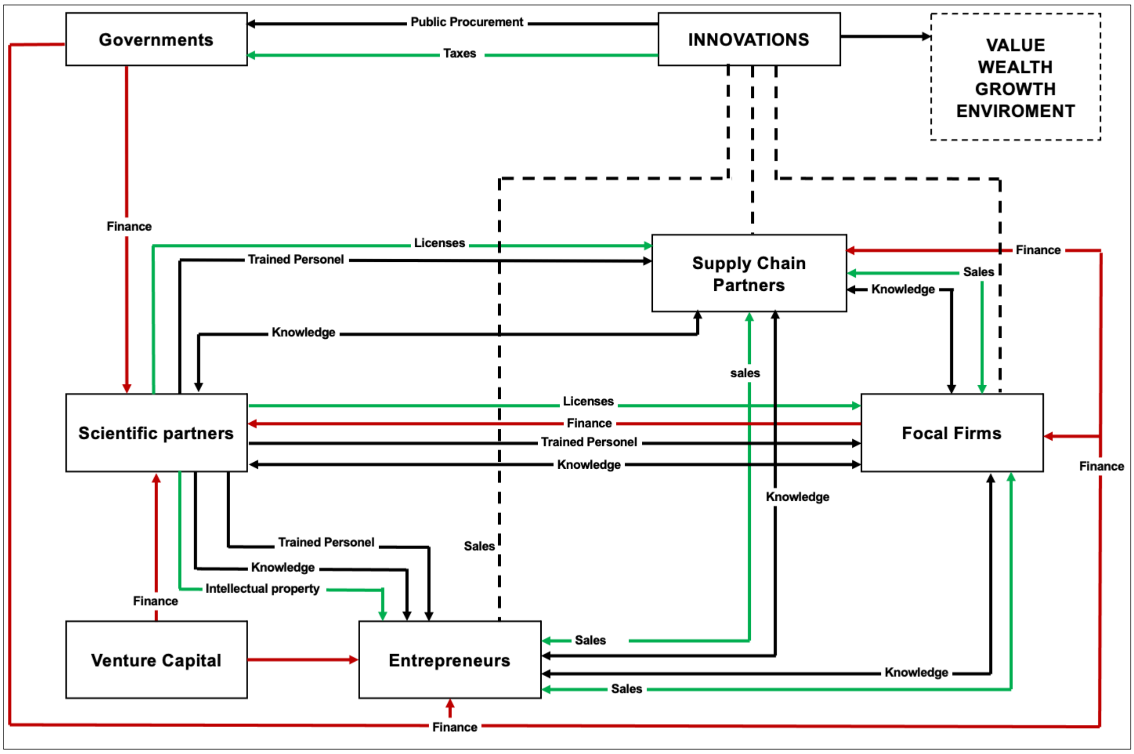
Venture capital: In the most financialised innovation ecosystems, venture capital funds provide crucial resources to promote entrepreneurship (Ács & Audretsch, 2005). In the European Union, these participants are still at an early stage of development (Bosma et al., 2018). However, in the future, they will play a crucial role in overcoming the "European paradox", which consists of being leaders in producing scientific knowledge, but not being able to market it via new companies (Fragkandreas, 2017).

Figure 1.2 schematically shows these actors and the relationships that can be established among them (Georghiou, 2015). The flexibility of the innovation ecosystem concept allows the analysis to be adapted to each type of context in which the interaction among the agents may vary. For example, in some innovation ecosystems such as Route 128 (Boston) and Silicon Valley (San Francisco), the role played by universities such as the Massachusetts Institute of Technology and Stanford University was crucial for the development of the innovation ecosystem (Saxenian, 1996). In other countries, such as Japan, the central government played a crucial role in guiding firms to develop innovations and invest in R&D activities (Freeman, 1987). In Israel, venture capital and startups played a more critical role in developing one of the most dynamic innovation ecosystems in the Middle East and the Mediterranean Sea (Brown & Mason, 2017).

1.3. Why focus on complementary and substitutive relations?

The ecosystem metaphor introduces the interaction among different organisms and how relationships can produce two extreme situations: mutual benefit (complementary relationships) or mutual harm (substitutive relationships) (Oh et al., 2016; Granstrand & Holgersson, 2020).

Figure 1.2. Relations among the main agents of the innovation ecosystem



Source: Adapted from Georghiou (2015)

On the one hand, complementary relationships mean that the results for both participants increase in terms of innovation, but also in terms of value creation. The generation of wealth and growth for the agents has positive repercussions for the rest of the agents in the ecosystem and for society as a whole (Thomas & Autio, 2020). In addition, in recent years, innovations have been introduced taking into account sustainability objectives, which further benefit society by reducing the environmental impact of the introduction of new products or processes (De Marchi et al, 2012).

On the other hand, tensions among actors can stop collective action and produce diminishing results (Budden & Murray, 2019, p. 28; Granstrand & Holgersson, 2020, p. 5). These negative results not only occur when the actors compete with each other but also when the actors cooperate (Ritala et al., 2013, p. 3). This undesired effect can be caused by the mechanism used, the incorrect alignment of objectives, or the existence of barriers to collaboration (Normann & Ramirez, 1993).

Analysing and understanding which relationships are most likely to increase innovation and which might lead to adverse outcomes is critical for managers and policymakers in order to make the right decisions (Funk, 2009). Some of the complex relationships that are particularly common and that require further analysis are the following:

Relations among different governments and companies: Previous studies have analysed the impact of specific government programmes for promotion. However, the existence of complementarity effects among different public programmes has been little analysed (Czarnitzki & Lopes-Bento, 2014; Huergo & Moreno, 2017). However, since most of these programmes have been implemented in states with a multilevel governance design, where regional, national and supranational institutions must align their objectives, analysing the complementary effects is crucial (Mulligan et al., 2019). Interaction can produce an increase in the innovation of the companies or a negative effect if they try to pursue non-aligned objectives (Flanagan et al., 2011).

Relations among governments, venture capital and entrepreneurs: Entrepreneurs and startups play a crucial role in creating radical innovations. However, their financial limitations often make it impossible to launch these new business models. Public funds, such as government-backed equity loans, are hybrid instruments with characteristics of loans and shares that allow companies to access funds without losing ownership. Despite their growing relevance, only Martí & Quas (2016) and Bertoni et al. (2019) have provided scientific evidence on their impact and which evaluates the effect of this financing tool. The first showed the positive effect of participative loans as a signal to private investors, and the second found substantial growth effects on young entrepreneurial firms concerning employment and sales. However, no study analyses the existence of complementarity between these aids and venture capital on the innovation of these companies and their impact on creating new business models.

1.4. Specific objectives and structure of this dissertation

1.4.1. Specific objectives

As previously stated, this dissertation aims to analyse the complementary and substitutive relationships among the main actors of innovation ecosystems. Analysing them all would be the work of one or several lives, and thus in this case, the focus will be on the relationships among **scientific, supply chain partners and focal firms**. To analyse these relationships, three specific research objectives, aligned with the construction of a theoretical research framework and the analysis of complementary and substitutive relationships were established:

The **first specific research objective** is to analyse the evolution of the literature on innovation ecosystems, trying to connect it with the previous literature on innovation systems. Due to the popularization of the innovation ecosystem concept among academics, companies and legislators, it is necessary to further the debate and enrich the concept with what previous analyses have theorized. Our objective is to find the complementarities between both literature streams and to be able to offer a joint research agenda so that studies on innovation can advance in the future far from labels and crossed vetoes.

The **second specific objective** is to study the relationships between firms and scientific partners, their types of partners and their impact on economic and innovative performance. The literature on innovation has determined that University-Industry collaboration is a critical relationship in the innovation ecosystem. In addition, it points out that these relationships increase the technical innovation of companies (patents, new knowledge) that translates into economic performance (invoicing of the innovative process(s), economic performance, productivity). Nevertheless, the following questions arise: Is this true? Do all types of university-industry relationships produce positive effects? Our objective is to measure the real impact of these relationships, considering the type of scientific partner, the mechanism chosen, and the result analysed.

The **third specific research objective** is to study the relationships between scientific partners, supply-chain partners and innovative companies.

Collaboration with different partners has been identified as a key process for companies' innovation. Traditionally, the literature that has analysed this mechanism has focused on individual partners or a number of partners but has omitted the combination of different types of partners and the complementary or substitutive effects that occur between them. Our goal is to measure the existence of complementary and substitute relationships between scientific partners and customers and suppliers capable of increasing the probability that companies will introduce key innovations for the whole of society.

1.4.2. Structure of this dissertation

1.4.2.1. Chapter 2: Bridging the gap between innovation ecosystems and innovation systems: A bibliometric review

Chapter 2 investigates the evolution of the literature on innovation ecosystems and innovation systems and the existence of complementarity between both scientific communities to offer a theoretical framework on which the following investigations can be based. Although, during the last decade, there has been an intense debate on the "ecosystem" metaphor, the popularization of the concept of "innovation ecosystem" among academics, companies and governments requires advancing the debate and enriching the concept with what both literature streams on innovation have discovered over the past four decades.

We analysed 6,500 scientific papers published between 1975 and 2021 related to innovation systems and ecosystems using a bibliometric analysis to achieve this goal. Specifically, we drew on impact analysis and scientific mapping to extract the most important publications, topics, and citations. Our findings reveal that three main themes can bridge the gap between both literature streams: i) Governance and legitimacy issues, ii) environmental innovations, and iii) co-creation and appropriation of value. The results of this work help academics, policymakers and practitioners to discover the differences and similarities between both concepts and establish a common framework for developing a joint research agenda.

1.4.2.2. Chapter 3: The impact of university–industry relationships on firms' performance: A meta-regression analysis

Chapter 3 focuses on the complementary relationships between scientific partners and companies. During the last quarter of a century, public resources have been disseminated widely to promote this relationship, and many studies have evaluated their results. However, while innovation theory identifies this relationship as a positive instrument for increasing firm performance, the empirical literature has reported various positive and negative results.

To overcome this conflict between theory and observed results, we conducted a meta-regression analysis based on 51 studies and 173 firm-level impact estimates published since 1995. After checking for publication selection bias, the sample and the heterogeneities of each study, our results show that the university-industry relationship produces a small-size effect on company performance. Furthermore, this effect is more significant for technical than for economic results. Through this analysis, we discover the determinants associated with positive results and explore some recommendations that companies, academics and governments can apply to improve innovation results when collaborating with scientific partners.

1.4.2.3. Chapter 4: External stakeholder engagement: Complementary and substitutive effects on firms' eco-innovation

Chapter 4 investigates whether collaboration agreements with different types of external partners produce complementary effects on the probability of introducing innovations with environmental objectives. Although the theories on external collaboration and open innovation affirm that the combination of external partners, such as scientific partners, suppliers and clients, produces complementary effects on the probability of introducing this type of innovation, several empirical studies have found the existence of substitution effects among them.

To resolve this conflict, we model the nature of the interaction between different external partners, analysing an unbalanced panel sample of 10,918 innovative Spanish companies from 2008 to 2016. Our results show that companies which simultaneously collaborate with scientific partners, suppliers, and customers obtain partial complementary effects, which increase the probability of firms to eco-innovate, and that the combination of customer collaboration with scientific partners, or supplier collaboration, produces partial substitution effects.

1.4.2.4. Chapter 5: General Discussion

Finally, Chapter 5 offers final comments, highlighting the main practical implications of the main studies of this dissertation for managers, academics and governments, as well as exciting ideas for future research in which the rest of the complex relationships are analysed.

CHAPTER 2. BRIDGING THE GAP BETWEEN INNOVATION ECOSYSTEMS AND INNOVATION SYSTEMS: A BIBLIOMETRIC REVIEW

Abstract

This paper investigates the evolution of innovation ecosystems and innovation system literature and the existence of complementariness between both scientific communities. Although during the last decade there has been an intense debate about the "ecosystem" metaphor, the popularization of the innovation ecosystem concept among scholars, companies and policymakers requires moving the debate forward and enriching the concept with what both literatures about innovation have discovered during the last four decades. We analysed 6,500 scientific documents published between 1975 and 2021 related to Innovation Systems and Ecosystems, using performance analysis and science mapping of both literatures by drawing evidence from publication activities, prominent themes, citation trends, and bibliographic coupling. Our findings reveal three main topics that can bridge the gap between the literatures: i) Governance and legitimacy problems, ii) environmental innovations, and iii) value co-creation and appropriation. This study will help scholars, business managers, and policymakers discover the differences and similarities between concepts as well as establish a common framework for developing a joint research agenda.

Keywords: Innovation Ecosystem; Innovation System; Literature Review; Bibliometric Analysis;

Earlier version of this chapter have been presented as “Bridging the Gap between Innovation Ecosystems and Innovation Systems: A Bibliometric Review” with José Ángel Miguel Dávila at the *31st Spanish Academy of Management International Conference* in Barcelona (2022) and submitted to a scientific journal for its review.

2.1. Introduction

Scholars have long observed that innovation results from complex relationships among firms and their business partners –suppliers, scientific partners, consumers, users, and governments. These set of relationships have been indistinctly named innovation systems and innovation ecosystems (Lundvall, 1992: Adner, 2006). While for a non-academic audience, the differences between both concepts are subtle, management and innovation scholars have engaged in a strong academic debate about the "ecosystem" metaphor (Oh et al., 2016; Ritala & Almpanopoulou, 2017). This debate has yielded this crucial topic for innovation studies, such as inter-organizational collaboration, value co-creation and industry evolution, which have been analysed from two different academic perspectives that, rather than converge and enrich each other, have grown apart and oppositional.

On the one hand, the Innovation System (IS) community has grown around the concept system of innovation co-theorised by Freeman (1982) and Lundvall (1992), with roots in Neo-Schumpeterian Economics. After more than forty years, the IS community has reached a high stage of institutional maturity, publishing journals such as Research Policy, organizing academic conferences such as Globelics, and guiding policy handbooks like the Oslo Manual (OCDE, 2018). The seminal national-level perspective of IS has been adapted to another context to create new approaches such as Regional Innovation Systems (Cooke et al., 1997), Triple Helix Models (Etzkowitz & Leydesdorff, 2000) and National Entrepreneurial System (Ács et al., 2014). Although this vast array of approaches has enriched the knowledge about IS, it has introduced a certain complexity that rather than being seen as a positive, has proven to be a limitation of the main theory to offer a general synthesis (Rakas & Hain, 2019).

On the other hand, the Innovation Ecosystem (IE) community has grown around the "ecosystem" metaphor (Moore, 1993). Unlike the IS concept, IE suffers from a lack of strong connections with economic theory, and has been connected with different theories such as the resource dependency theory (Adner & Kapoor, 2010), open innovation (Xie & Wang, 2020) and dynamic capabilities theory (Heaton et al., 2019). This lack of theoretical background has limited the expansion of the term due to a lack of academic legitimation, specifically in innovation studies. In the last decade, prominent scholars such as Autio & Thomas (2014) and Ritala & Almpanopoulou (2017) have encouraged IE scholars to focus on the theoretical foundations of the construct to give it a solid platform on which to grow. However, despite all these problems, the concept of IE has not stopped growing among consultancy services (e.g., BCG, Deloitte) and policy designers (e.g., European Innovation Ecosystems).

During recent years, some scholars have tried to merge both concepts through intermediate theories such as "Regional Innovation Ecosystems" and "National Entrepreneurship Ecosystems". For example, Feldman et al. (2019, p. 4) argue that the ecosystem perspective reorients the discussion away from static relationships toward dynamic interactions. Arora et al. (2019, p. 3) claim that the US innovation ecosystem is based on universities and other public research institutions, large corporations, individual inventors, small firms and science-based start-ups. The efforts to connect both literatures, have been analysed by previous literature reviews such as Faissal Bassis & Armellini (2018) and Suominen et al. (2019), who have found some topics which can connect both communities. However, although these works have greatly enriched the opportunities that both theories directly share, our perception is that there are also hidden bibliographic connections that contribute to a greater understanding of the possible cross-fertilisation between both theories.

This study aims to answer the following research question: What are the hidden connections between innovation systems and innovation ecosystems literatures First, we review the IS and EI concepts and their theoretical approaches. Second, we clarify to what extent both theoretical frameworks differ and complement one another by systematically reviewing the bibliometric connections of both clusters based on 6,500 scientific documents. Finally, we critically discuss our main results and focus on bibliography-coupling analyses to build a common framework for further research. Our analysis shows three main research lines from which both literature streams could mutually benefit: i) Governance and legitimacy problems, ii) environmental innovations and iii) value co-creation and appropriation.

The paper is organised as follows. The next section reviews pertinent literature on innovation systems and the innovation ecosystem. Section 2.3 presents the bibliometric methodology used to analyse the literature. Section 2.4 presents the results from the performance analysis and the science mapping. Section 2.5 discusses the result and presents a future research agenda, and Section 2.6 explains the main conclusions and limitations.

2.2. Literature review

2.2.1. Innovation Systems

The Innovation System (IS) concept emerged in the earlier 1980s, co-developed by Prof. Cris Freeman and Prof. Bengt-Åke Lundvall during a research stay of the former at Aalborg University (Denmark). Although previous scholars such as Bowers et al. (1981) used the engineering concept of 'technological systems', referring to the complex social systems required to develop high-tech artifacts, it was Prof. Lundvall who used the concept of "systems of innovation" for the first time to refer to the linkages between producers and users (Lundvall, 1985, p. 29). However, Prof. Freeman popularized the concept in his book about the Japanese economy: "Technology Policy and Economic Performance: Lessons from Japan" (Freeman, 1987). Finally, the theoretical framework was established by Lundvall (1992), who brought together all previous contributions analysing and packaging the different dimensions of the IS concept and giving them a national perspective. The concept was rapidly adopted from the first moment by scholars and policymakers.

The fast adoption of the Innovation System (NIS) is explained due to its emergence at the crucial moment for being a critical response to the dominant non-interventionist economic point of view during the 70s and 80s. The IS theory tried to explain why country growth rates differed and how they could build an absolute advantage in structural competitiveness by relying on technology development and innovation guided by the government (Nelson, 1993). Although, during the same period, other intervention theories fostered the same recommendations (clusters, innovative milieus, industrial districts), the National perspective of IS played a critical role in the government's adoption of its policy recommendations (Capron et al., 1998).

In addition, IS theory produced a major change in innovation studies, stablishing the foundational frameworks of the literature as we know it today but its popularity also resulting in some authors deciding to introduce some modifications to the theoretical backgrounds to enable them to include their own point of view. For example, Cooke et al. (1997) consider that the national perspective could be helpful for small countries but that it would better to focus on the regional level in medium and big countries. Their perspective gained a lot of attention when the European Union started to work with the "Europe of the Regions" framework. Others, like Viotti (2002), argued that in the late industrialising economies, the process of technical change is not innovation, but learning and absorption of technologies already existing in the industrialized economies, and they coined the concept of National Learning Systems. Etzkowitz & Leydesdorff (2000) developed the “Triple Helix Model" analysis which operates based on neo-evolutionary and neo-institutional perspectives focusing on the interactions among universities, industries and governments.

Nowadays, most parts of this second literature stream have been abandoned or replaced by new theoretical foundations such as the Technological Innovation System (Markard & Truffer, 2008) and National Systems of Entrepreneurship (Ács et al., 2014). Markard & Truffer (2008) define their approach as the dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure involved in technology generation, diffusion, and utilization. While Ács et al. (2014, p. 11) attempt to explain the differences between countries and regions based on individual entrepreneurial activities. Both recent theories have abandoned the classical university-industry inter-organizational collaboration studies and the analysis of R&D policy. They have focused on industry evolution, collaboration networks, the role played by entrepreneurs and the transition from one technological system to another (Rakas & Hain, 2019).

Finally, the variety of literature streams linked to the SI concept has greatly increased the understanding of the innovation phenomenon, but as Rakas & Hain

(2019, p. 3) argue, an excessive and non-coherent "exploration" led to a fragmentation of the research field and limited its ability to produce deep and meaningful insights and results. In addition, they point out the need to return to a management and organization perspective, focused on a firm-level analysis for a new synthesis (Rakas & Hain, 2019, p. 19). Similarly, Schott & Steinmueller (2018) have pointed out that the IS literature must address three topics: i) innovation for growth, tapping the potential of science and technology for prosperity and nurturing socio-technical systems, ii) Global Innovation Systems and iii) the aspirations for transformative change which have been captured in the UN Sustainable Development Goals.

2.2.2. Innovation Ecosystem

The innovation ecosystem concept is derived from the Business Ecosystem construct (Moore, 1993). The business ecosystem term emerged in the earlier 1993s in an article published in Harvard Business Review by Moore (1993). He linked the concept of business strategy and competition with the concept of coevolution from ecology studies (Bateson, 1979). In his book, "Leadership and Strategy in the Age of Business Ecosystem" (Moore, 1996), he argued that the business ecosystem covers not only 'focal firms' industry but also other industries connected through technology, suppliers and consumers. He argued that companies from different industries upstream or downstream of the supply chain coevolve capabilities around innovation in business ecosystems working cooperatively to develop new products, satisfy customer needs, and eventually incorporate the next round of innovations. Next, Iansiti & Levien (2004) argued that, like a biological ecosystem, a business ecosystem is founded on loose connections among the agents and not on formal agreements. For Iansiti and Levien (2004, p. 76), interdependencies mean that "the company must share the fate of the other participants in the ecosystem" while at the same time having an independent value proposition.

The business ecosystem concept emerged as a critical response to the management perspective, which believes a firm's decisions and strategy must be purely competitive with other firms and not a co-operative relation (Walley, 2007). Close inter-firm collaboration and an open innovation perspective enable technological advancements in interconnected business ecosystems (Masucci et al., 2020). The theoretical core explains how firms' value creation and evolution are determined by the complex interaction produced inside a business ecosystem (Teece, 2016).

After this first wave, Adner and his colleagues developed the innovation ecosystem as the structure of technology interdependence (Adner, 2012; Adner & Kapoor, 2010; Leavy, 2012). In his book "The Wide Lens: What Successful Innovators See That Others Miss" (Adner, 2012), he states that his work is a continuation of Moore's (1993). Both of them analyse how the structure of technological interdependence impacts firm performance and "how to develop an innovation strategy in an innovation ecosystem. For the IE literature, long-term wealth and innovation are determined by relationships rather than transactions (Kandiah & Gossain, 1998). In terms of shared capabilities, Wikhamn (2013) show how IE can enable value creation strategy conducted outside the company's boundaries by structuring an open innovation model (Autio & Thomas, 2014; Bomtempo et al., 2017, p. 221). Likewise, Gawer and Cusumano (2014) claim that in the IE, the value co-creation process is set to create more value for the ecosystem's end users together than the individual players could generate as independent actors.

Recent works such as that of Granstrand and Holgersson (2020, p. 3) have defined innovation ecosystems as a broad concept which includes the evolving set of actors, activities, and artifacts as well as the institutions and relations, including complementary and substitute relations, which are important for the innovation performance of an actor or a population of actors. In this way, the concept of an innovation ecosystem can be very valuable and appropriate for modelling the economic dynamics of complex relationships (Adner, 2012). Unlike previous research on IS which focuses on the interactions of its two static construct elements, this approach focuses on the existing complex and dynamics relations produced by the crucial actors (universities, suppliers, costumers, focal firms, governments), their output (patents, new products, new processes) and their relations (collaboration agreements, service research, funding).

2.3. Research strategy, methodology and data

Following previous bibliometric studies (Di Vaio et al., 2021; Dontu et al., 2021), this study is based on a system of quantitative techniques encapsulated in the bibliometric methodology (e.g., citation analysis, units of publication and citation networks). Our research was divided into two phases: The extraction and review of the relevant documents and their bibliometric analysis.

First, to identify the current state of the research of IS and EI literature, a systemic search (see Table 2.1) was performed on the ISI Web of Science database using the Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Emerging Sources Citation Index (ESCI), Book Citation Index– Social Sciences & Humanities (BKCI-SSH) and Book Citation Index– Science (BKCI-S). At this level, time limits were not enforced explicitly so that all the inputs on this topic could be recollected. Because our search terms were explicit and related to IS and IE literature (excluding other variations such as business ecosystems and national entrepreneurs' systems), we decided not to apply any excluding criteria. This protocol search provided us 6,500 documents collected between 1971 and 2021.

Table 2.1. Concepts, search terms and search stings

Concept	Search Terms
Innovation System	"Innovation System" OR "Innovation Systems" OR "System of Innovation" OR "Systems of Innovation"
Innovation Ecosystem	"Innovation Ecosystem" OR "Innovation Ecosystems"
WOS Search Protocol: 6,500 Results	"Innovation System" OR "Innovation Systems" OR "System of Innovation" OR "Systems of Innovation" (Topic) or "Innovation Ecosystem" OR "Innovation Ecosystems" (Topic) Editions = BKCI-SSH, BKCI-S, ESCI, SCI-EXPANDED, SSCI.

Source: Own elaboration

The second move consisted of the bibliometric analysis, divided into the descriptive analysis and source mapping. The descriptive analysis summarises the constituents' contributions to a field (Cobo et al., 2011). Descriptive analysis is the hallmark of bibliometric studies, and it can be found in most reviews' articles. It presents the performance of different research constituents (e.g., authors, institutions, countries, and journals). At that point we applied what is known as Source Mapping, which allowed us to analyse the intellectual interactions and structural connections among research constituents. This analysis shows the research field's bibliometric and intellectual structures using techniques such as citation analysis, co-citation analysis, bibliographic coupling, and the co-word analysis combined with network analysis (Donthu et al., 2021).

2.4. Data analysis and results

The quantitative analysis of the selected papers is comprehensive in subsections based on performance analysis and science mapping. We analysed several publications trends in IS and EI literature using bibliographical information drawn from WOS databases.

2.4.1. Descriptive Analysis

2.4.1.1. Keyword analysis

Table 2.2 displays the ten most-used keywords of authors for tagging their research. As can be seen, innovation is the main keyword, followed by the different innovation system taxonomies—Innovation systems, Regional Innovation System, National Innovation System—followed by Innovation Ecosystem appears. Other crucial keywords that appear are China, Entrepreneurship, Open Innovation, and Sustainability. The explanation for these keywords is as follows. First, China is trying to study innovation phenomena to become the leading nation in technology (Lundvall and Rikap, 2022). Second, entrepreneurship has been one of the main drivers of innovation since the beginning of innovation studies (Ács et al., 2014; Spigel, 2017). Third, open innovation is literature having a lot in common with both scientific communities. For example, Xie & Wand (2020, p. 28) identify several equivalent multidimensional paths for firms to achieve high-level product innovation in open innovation ecosystems. Finally, sustainability is one of the main topics in innovation studies (Masucci et al., 2020). Firms and external stakeholders are trying to develop and introduce environmental innovations, also known as eco-innovations, to reduce their environmental impact.

Table 2.2. Most-used keywords

Author Keywords	Frequency	% (N = 11,386)
Innovation	777	6.824
Innovation System/s	579	5.085
Regional Innovation System/s	348	3.056
National Innovation System/s	260	2.284
Innovation Policy	232	2.038
Innovation Ecosystem	202	1.774
China	186	1.634
Entrepreneurship	122	1.072
Open Innovation	115	1.010
Sustainability	97	0.852

Source: Own elaboration

2.4.1.2. Documents type and main source

Table 2.3 provides a detailed overview of the different types of analysed documents. Research articles were (at 89.89%) the document category containing the biggest number of documents in the sample. Surprisingly, this is followed by reviews (6.05%), which could be explained as the degree of maturity of the IS or IE literature and the important number of books recorded in WOS.

Table 2.3. Main Documents type

Documents Types	Frequency	% (N = 6,500)
Articles	5843	89.892
Reviews	393	6.046
Editorial Material	197	3.031
Book	42	0.646
Others	25	0.385

Source: Own elaboration

Table 2.4 lists the most successful scientific journals. Research Policy is the journal which focusses most on IS literature. This makes sense because Prof. Chris Freeman was of one the journal's founders. In addition, other journals highly-connected with innovation studies, such as Technological Forecasting and Social Change, are focused on socio-technical innovation, European Planning Studies and Regional Studies are focused on the regional version of IS. At the same time, Technology Analysis & Strategic Management focuses on IE and Sustainability, Journal of Cleaner Production, Environmental Innovation and Societal Transitions on environmental innovations.

Table 2.4. Main Sources

Sources	Articles
Research Policy	301
Technological Forecasting and Social Change	280
European Planning Studies	213
Sustainability	158
Science And Public Policy	110
Regional Studies	103
Technology Analysis & Strategic Management	103
Scientometrics	99
Journal of Cleaner Production	89
Environmental Innovation and Societal Transitions	86

Source: Own elaboration

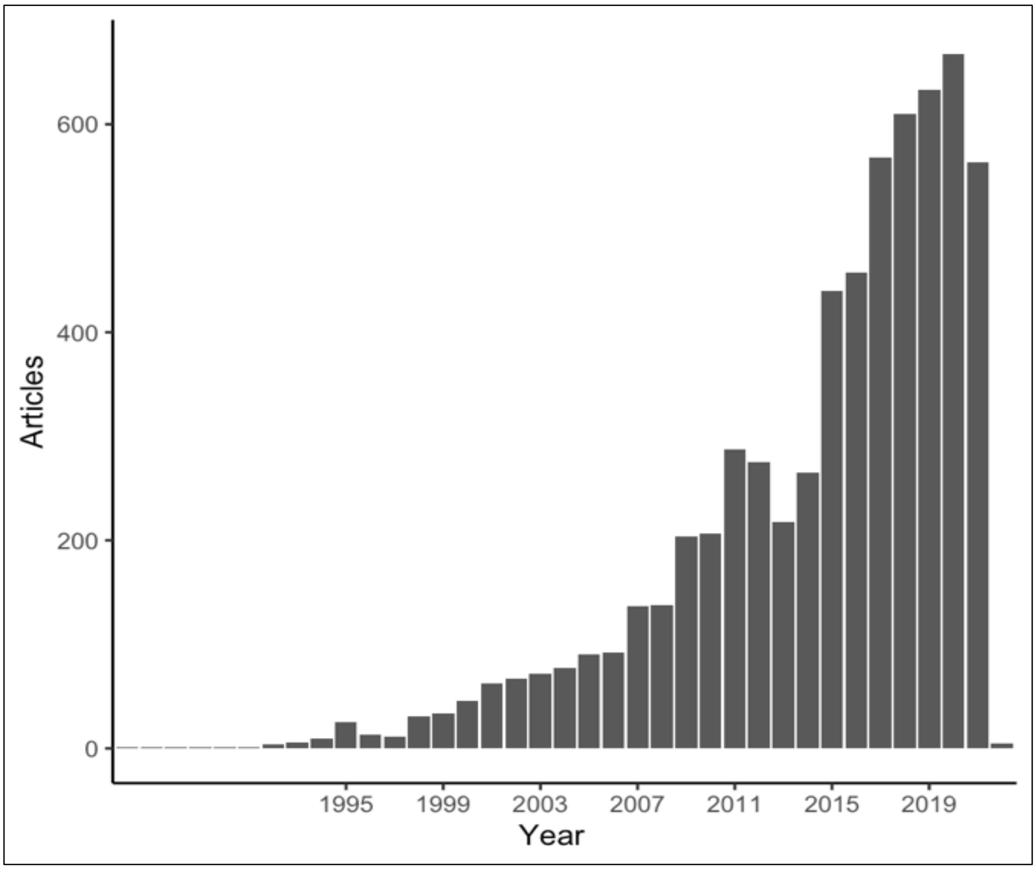
2.4.1.3. Evolution of published documents

Figure 2.1 illustrates the evolution of publications on the current subject from 1975 to 2021, during which period there was a steady increase in IS and IE publications. From 2010 to 2014, the number of publications shows stabilization produced by the maturity of the IS concept and a sharp increase up to 2020 due to the development of IE.

2.4.1.5. Most productive authors

Table 2.5 lists the most productive authors. Most of them are related to the different taxonomies of IS. L. Klerx is the author with the most documents. His research is based on agricultural innovation studies focusing on the institutional change in research and advisory organizations, roles and positions of organizations that broker multi-stakeholder networks for innovation, and implementation of trans-disciplinary science and co-innovation approaches. Next, other authors appear such as M. P. Hekkert, L. Leydesdorff, M. Trippl, B. Ruffer, L. Coenen, and P. Cooke. These authors are the second wave of IS, involved in developing the concept of the Triple Helix, Technological Innovation, and Regional Innovation Models.

Figure 2.1. Evolution of published documents



Source: Own elaboration

Table 2.5. Most productive authors

Most productive authors	Articles	Theoretical Perspective
Klerx, L.	66	Triple Helix Model
Hekkert, M. P.	45	Socio-technical Innovation System
Leydesdorff, L.	37	Sustainability transition
Trippl, M.	32	National Innovation System
Ruffer, B.	30	Sectoral Innovation System
Coenen, L.	29	Regional innovation System
Cooke, P.	28	Technological Innovation System
Carayannis, E. G.	25	Regional Innovation System
Isaksen, S.	23	National Innovation System
Leeuwis, C.	23	Agricultural innovation System

Source: Own elaboration

2.4.1.6. Citation Analysis

The citation analysis looks at the impact of a piece of research regarding the degree to which it has been helpful to other researchers (Bornmann et al., 2008). Citations are used to indicate that a publication has utilized information from other research (including others' ideas, research results, etc.); thus, the number of citations listed in a research assessment serves as a determiner of the influence of the research. Table 2.6 shows the most cited documents.

Table 2.6. Most cited documents

Reference	Total cites	Theoretical Perspective
Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and “Mode 2” to a Triple Helix of university–industry–government relations. Research Policy, 29(2), 109–123.	3003	Triple Helix Model
Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems. Research Policy, 33(6–7), 897–920.	1509	Sectoral Innovation Systems
Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. Research Policy, 41(6), 955–967.	1259	Sustainability transitions
Freeman, C. (1995). The “national system of innovation” in historical perspective. Cambridge Journal of Economics, 19(1), 5–24.	1135	National Innovation System
Malerba, F. (2002). Sectoral systems of innovation and production. Research Policy, 31(2), 247–264.	1108	Sectoral Innovation Systems
Cooke, P., Gomez Uranga, M., & Etxebarria, G. (1997). Regional innovation systems: Institutional and organisational dimensions. Research Policy, 26(4–5), 475–491.	1102	Regional innovation Systems
Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. H. M. (2007). Functions of innovation systems: A new approach for analysing technological change. Technological Forecasting and Social Change, 74(4), 413–432.	1079	Technological Innovation System
Tödtling, F., & Trippl, M. (2005). One size fits all? Research Policy, 34(8), 1203–1219. https://doi.org/10.1016/j.respol.2005.01.018.	1024	Regional Innovation Systems
Furman, J. L., Porter, M. E., & Stern, S. (2002). The determinants of national innovative capacity. Research Policy, 31(6), 899–933.	953	National Innovation System
Adner, R., & Kapoor, R. (2010). Value creation in innovation ecosystems: how the structure of technological interdependence affects firm performance in new technology generations. Strategic Management Journal, 31(3), 306–333.	935	Innovation Ecosystems

Source: Own elaboration

Etzkowitz & Leydesdorff (2000) top the list with their widely-cited article The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry–government relations, which identifies and analyses how national innovation systems evolve into a triple helix analysis based on sub-dynamics (university, industry and government). The second one is from sectoral innovation systems to socio-technical systems (Geels, 2004). This article contributes to the perspective of sectoral innovation systems (Malerba, 2002), analysing long-term dynamics and offering an analytical distinction between systems, actors involved in them, and the institutions which guide actors' perceptions and activities. Finally, it also appears to work like Adner (2010)'s related to innovation ecosystem literature entitled value creation in innovation ecosystems: how the structure of technological interdependence affects firm performance in new technology generations.

2.4.2. Science Mapping

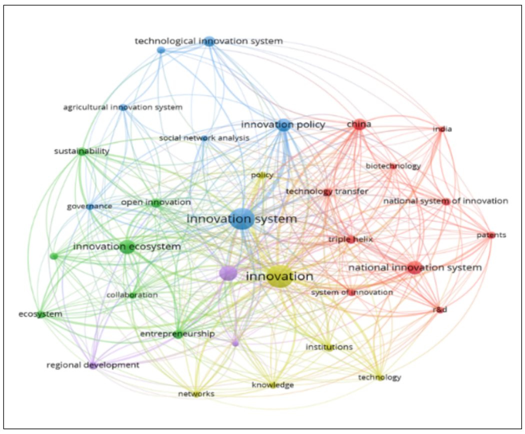
An organized approach was adopted to investigate and display keyword networks using VOSviewer. A map is developed based on the details from the bibliography. The "association strength" standardises the association principles relating to keywords, authors and references (Van Eck & Waltman, 2010). The Visualization of Similarities (VOS) approach is used to position each word on the map graphically (Van Eck & Waltman, 2010). Finally, the VOS-viewer algorithm provides different resolution parameters for detecting the various clusters. The entire power correlations were determined, resulting in four main distinct clusters of colours (green, red, yellow and blue). The circle's size corresponds to the frequency of an apparent term; the greater the frequency of summaries, the bigger the size (Van Eck & Waltman, 2010). The colours of the circles in the search were observed parallel to the numerous clusters. The distance between the circles is informative: the shorter the distance, the stronger the relation.

2.4.2.1. Keywords co-ocurrence

This study nullified and picked 50 keywords. The graphics of co-words or keywords coincidence are seen in Figure 2.2 and the structure of ideas or information from earlier to the last literature developments are described in Figure 2.3.

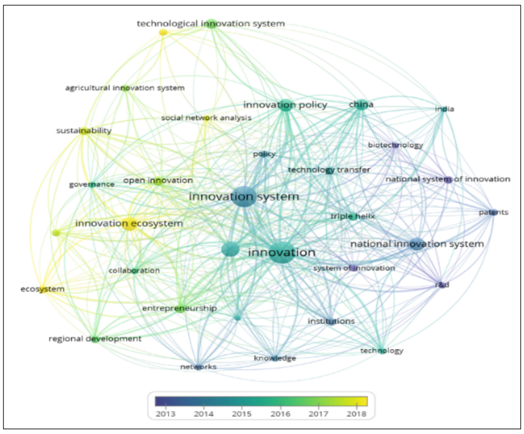
Figure 2.2 shows four clusters: First, innovation system literature in blue. This cluster includes keywords like technological innovation system, agricultural innovation system, social network analysis, and innovation policy. Second, national innovation systems in red: Biotechnology, technology transfer, triple helix, R&D, biotechnology, India or patents. Third, the Innovation ecosystem cluster (green) includes open innovation, ecosystem, collaboration, entrepreneurship and sustainability in green. Finally, in yellow, we have a small cluster which includes technology, institutions, knowledge networks and policy.

Figure 2.2. Visualization of co-word network based on author keyword



Source: Own elaboration

Figure 2.3. Overlay visualization of co-word network based on author kw



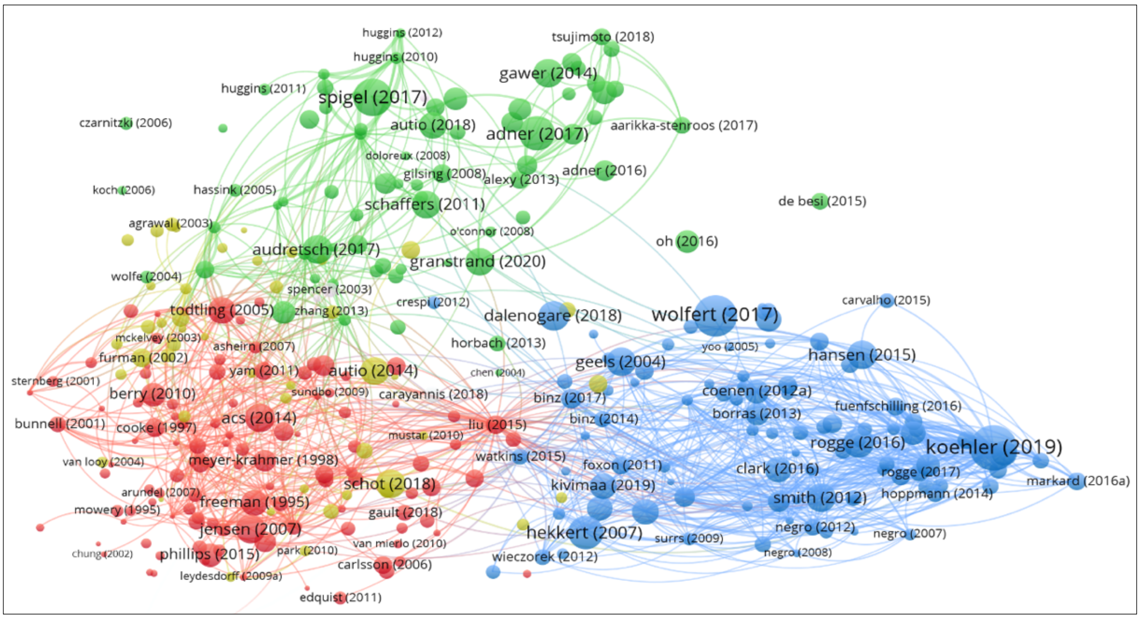
Source: Own elaboration

Figure 2.3 shows the evolution of the keywords used with a time dimension. In dark blue (the oldest terms) authors used keywords like National Innovation system, patents, R&D or institutions. These first keywords are the same which shape the red cluster previously mentioned the most recent terms are those related with innovation ecosystem like open innovation, technological innovation system or social network analysis. Both clusters are related between medium-age keywords like entrepreneurship, regional development, collaboration, innovation policy or knowledge.

2.4.2.2. Bibliographic Coupling

Bibliographic coupling links documents that reference the same set of cited documents. The advantage of this science mapping is that in a longitudinal dataset where links are restricted to those within the set, bibliographic coupling is able to cluster very recent papers but clusters fewer of the very old papers. In contrast, co-citation clustering does the opposite—it clusters the older papers but cannot cluster the most recent papers that have not yet been cited.

Figure 2.4. Visualization of bibliographic coupling



Source: Own elaboration

Figure 2.4 shows the visualization of bibliographic coupling links showing the existence of four main clusters. The first one is the innovation system cluster (red) which appears connected to Freeman (1995), Jensen et al. (2007) but also others such as Ács et al. (2014) and Cooke et al. (1997). Second, a blue cluster appears in which documents such as the one produced by Wolfert et al. (2017), Köhler et al. (2019) and Kivimaa et al. (2019) focus on sustainable transitions. Third, in green, the innovation ecosystem cluster with works like Adner (2017), Spigel (2017) and Grandstard & Holgersson (2020) appears. Finally, a small yellow cluster appears in studies such as Autio and Thomas (2014) or Schot & Kanger (2018), which have links which try to connect with other clusters, especially the innovation system cluster but do not have connections between them.

2.5. Discussion

We used data from 6,500 innovation systems and innovation ecosystems studies to examine how both literature streams have evolved in the last four decades, the connections between them and the gaps that need to be closed. Our analyses show a performance orientation based on the individual metrics of each study and a science mapping in which we analyse the connections between the documents using the authors' keywords and the bibliographic coupling. The performance analysis defines the dominant literature streams and the most-used theoretical perspective. Next, the science mapping shows the hidden connections between IS and EI and uncovers new literature clusters. In the following lines, we discuss the previous results, addressing each of them.

First, the performance analysis of the literature shows us the dominance of the IS literature over the years. This trend is aligned with the growth of the innovation studies community (Rakas & Hain, 2019). Table 2.2 shows that the most-used keywords are related to IS and its versions and that innovation ecosystems only appears in sixth place. Our research protocol can explain these results. It stands out that the most-cited papers are related to IS variations rather than focused on the seminal national IS perspective. This explains the widespread influence of the Freeman (1987) and Lundvall (1992) theories on other perspectives. During the first decade of this century, IS settled the foundations of new paradigms such as socio-technical systems (Geels, 2004), sectoral systems (Malerba, 2002) and the Triple-Helix model Etzkowitz & Leydesdorff (2000). However, it stands out that among the most-cited documents, the most recent ones are Adner & Kapoor (2010) and Markard et al. (2012). The former is one of the seminal articles for the IE literature, and the latter is focused on sustainable transitions. A transition involves far-reaching changes along different dimensions: technological, material, organizational, institutional, political, economic, and socio-cultural, focussed re-orientating the socio-technical paradigms towards environmentally sustainable goals. This literature stream is highly connected with the works published by some authors who appear in Table 2.5, such as Klerx & Leeuwis.

Second, our science mapping shows us that the connections between the IS and IE literature are being made through the analysis of the role played by entrepreneurs (Autio et al., 2014), specific industrial context (Dalenogare et al., 2018), complementary or substitutive relations among the agents (Granstrand & Holgersson, 2020) and environmental innovations (Hobarch et al., 2013). The advances in these crucial topics make a lot of sense if we consider the degree of maturity of both clusters. IS has a high level of maturity in which the advances have to be done in the grey areas, focusing on new concepts not considered by the foundational topics. Innovation studies are advancing at the system's margins as "entrepreneurs" or "social network analysis". However, as shown in Figure 2.3, IE literature has grown as a part of the IS literature despite the fact that there could be an obvious cross-fertilization based on topics such as governance, collaboration or sustainability, as the analysis of co-keywords shows (Figure 2.2).

Third, another interesting point extracted for our bibliometric review is discovering the importance of sustainability literature hidden in the IS and EI clusters. Environmental innovations, also known as eco-innovations, have been partially analysed by IS and EI (Horbach et al., 2013). IS has approached this research topic by analysing how, for example, the collaboration between external partners promotes eco-innovation (De Marchi, 2012) and agricultural innovation systems to develop a sustainable agricultural model of proximity (Köhler et al., 2019). EI literature has established a remote connection to this cluster, but from a management perspective, environmental issues are undeniably threatened from the customer and supply sides. Only recent works such as Yang et al. (2021) have addressed this topic from this perspective, analysing how government-university-industry foster cleantech innovation in a green innovation ecosystem.

2 5.1. A Future Research Agenda

Our bibliometric analysis shows that IS- and IE-literature have grown apart and have focused on different topics since their seminal papers. The IS community has been developed mainly in traditional manufacturing and incremental learning, focusing on policymaking, while the IE community has looked only at innovative clusters and dynamic industries in which novel and rapidly changing technology has appeared. Although they are two different literature streams, both have focused on similar topics during the last years. They are on those where we see potential complementarities concerning both literatures. In the next paragraphs, we explain the complementarity topics identified that could configure a joint research agenda between both literature clusters.

Governance and Legitimacy problems: As Granstrand & Holgerssonm, (2020) pointed out, innovation is the result of complementary and substitutive relations among crucial agents. In these complex relations, how the networks are organized and what legitimacy the focal firm has to dominate the ecosystem has been widely analysed from the IE perspective (Thomas & Autio, 2020, p. 14). However, the governance and legitimacy problems have been analysed regarding the socio-technical systems from a public perspective, focusing on how social institutions such as regulation, and routines, influence the evolution and collaboration among the agents (Könnölä et al., 2021, Borras & Edler, 2014, p. 30). Despite these differences, for both approaches' governance problems reduce the innovation outcome and produce a negative effect on society. The link between perspectives could be established through the notion of transformative governance, which seeks to improve the adaptiveness and resilience of the ecosystem and orchestrate socio-technical transformation to pursue win-win situations. This concept connects the IE-perspective of non-contractual or informal governance with the IS concept focused on formal laws and regulations. Nowadays, policymakers are starting to legislate platform ecosystems to regulate the exchange or the relations between the focal agents and the rest of the stakeholders. In this process of formalising the relationships, the concept of legitimation would play a crucial role in establishing the dominant positions and future legislation based on the relations in the innovation ecosystem (Autio & Thomas, 2022).

Environmental Innovation: Environmental innovation or eco-innovation consists of creating new or modified processes, techniques, systems and products to avoid or reduce environmental damage (Horbach et al., 2013). This topic is crucial for the sustainability transitions and IE literature. For example, Yin et al. (2020) argue that an innovation ecosystem approach will understand better how sustainable and smart products (SSP) are developed. And, Oliveira-Duarte et al. (2021) offer a similar point of view, arguing that the innovation ecosystem could address Sustainable Development goals from a non-regional perspective, focusing on the collaboration between focal firms, suppliers and users. This task is aligned with what Schot & Steinmuller (2018) argue regarding what IS literature has to analyse in the future. In this topic, IS has focused on how to increase the firm's likelihood of eco-innovation, while IE has focused on the case analysis. Here Sustainable transition literature could be the link between both main theories. In the last decades, sustainable transitions have grown from a socio-technical perspective that is not very far removed from the business ecosystems perspective that analyses specific technologies in specific contexts. A further development of the research on how mature industries could benefit from creating an innovation ecosystem to develop sustainable technologies could link the two industries.

Value co-creation and appropriation: As the relationships between firms and their business partners have become more crucial for business success, the value creation and appropriation process has become more complex (Adner, 2017). This value co-creation cannot be fully understood by considering only individual agents but rather must be understood through innovative technologies and artifacts. Hence, understanding how formal and informal relationships bind actors in an ecosystem must be a future joint research line for both literatures. A common approach could be network analysis, qualitative analysis non-linear analysis rather than focusing on individual collaboration agreements. For example, Grèzes et al. (2016) analyse the case of value co-creation using a regional innovation system perspective. Network theory could help the IS literature adapt to the IE perspective. The impact of high external innovation challenges on the focal firm depends on whether the challenges are confronted by suppliers, customers, or complementors. However, the IE literature has focused on private agents. Still, it has analysed the collaboration with public agents such as universities, which could address the innovation challenge of collaborating with the firms. It has been widely analysed in the IS literature (Clarysse et al., 2014; Carayannis et al., 2018).

2.6. Conclusions

To address the research question regarding the connections between IS and IE literatures and to build a common framework for further research, this paper has presented the results of a literature review based on a robust empirical bibliometric analysis of 6,500 documents dated between 1975 and 2021, followed by a critical discussion of the results. Our results show the domination of IS literature during the period 2000-10, the growth of IE theory in the period 2010-2020, and the existence of a hidden cluster on sustainable transitions for both literatures. Our critical examination of the results shows three shared topics that could connect both literature streams in the future: i) ecosystem governance and legitimacy, ii) environmental innovation, and iii) value co-creation. These three topics could be influenced in cross-fertilization between both literatures' steams in terms of academic literature and institutional journals or scientific associations. This movement is already happening, and Classical IS journals such as Research Policy are publishing special issues about IE as well as Industry and Innovation.

Our results provide three main contributions to both scholars' communities. First, although previous attempts have tried to analyse the links between IE and IS studies, they have not analysed the bibliographic coupling in depth. In our research, we have discovered the importance of environmental and sustainable innovations for the first time. This is a major contribution of our paper in comparison with previous analyses such as the one done by Faissal Bassis & Armellini (2018) and Suominen et al. (2019). Second, our bibliometric approach could help identify the necessary bridges between both theories and create a new synthesis, as Rakas & Hain (2019, p. 19) suggest. Accordingly, we could move forward from the narrow perspective of the incorrect use of the "ecosystem" metaphor (Oh et al., 2016) by going further in this debate and focusing on the connections between both topics and the institutional context, also integrating other literatures such as open innovation and entrepreneurial ecosystems.

Finally, there are two limitations that our readers should consider. First, the data set was gathered with a protocol which excludes other versions of "ecosystems" such as "business ecosystems", "knowledge ecosystems" or "platform ecosystems" (Autio & Thomas, 2022). This is because our protocol focuses on the innovation perspective and has excluded others more focussed on entrepreneurial agents or open innovation contexts. Future literature reviews could explore this hidden spot to discover new research goals for merging highly-related literature streams. Second, the general increase in the number of references in academic literature may have created some biases in the results in favour of hot topics such as Innovation Ecosystems.

To conclude, we suggest that scholars should create shared conferences and institutional places to debate the intellectual roots of their concepts and try to establish a research agenda. As we have said, the innovation ecosystem is a concept growing in society and policy designers (e.g., European Innovation

Ecosystems) and the audience needs to benefit from the understanding of complex relationships among firms and their business partners which both communities have developed over the years to increase innovation, new opportunities and value creation.

CHAPTER 3. THE IMPACT OF UNIVERSITY – INDUSTRY RELATIONSHIPS ON FIRMS' PERFORMANCE: A META-REGRESSION ANALYSIS

Abstract

The University–Industry relationship is a fundamental part of innovation systems. A wide spread of public resources has been given to promote this relationship and a large number of studies has evaluated the results. However, while innovation theory identifies this relationship as a positive instrument to increase firms' performance, evaluation literature reports a wide range of findings. The lack of conclusiveness results in theory and evaluation literature motivates this meta-regression analysis, built on fifty-one micro-level studies published since 1995. After controlling for publication selection bias, sample, and study heterogeneities, our results show a small effect on firms' performance. Specifically, the size of the effect is more significant for technical outcomes than economic ones. These findings have a lot of relevance for universities, firms, and policymakers for determining open-innovation strategies and public policies.

Keywords: university–industry collaboration; meta-regression analysis; STI; firm performance

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3.1. Introduction

Since the early literature on technological change (Allen & Cohen, 1969; Arrow, 1974), academics and practitioners reckon that firms cannot only rely on their internal resources; but rather that acquisition of external knowledge is a key determinant for their innovation and performance (Cohen et al., 2002). Collaboration with different types of organizations such as customers, suppliers, and research partners are considered to be the primary source of external knowledge (Belderbos et al., 2004; Jensen et al., 2007; Nieto & Santamaría, 2010). Specifically, collaboration between universities and industries is a driver of knowledge-transfer related to research, science, and technology (Metcalfe, 1995; Hagedoorn et al., 2000; Hall et al., 2003).

Literature on university–industry (U–I) collaboration has identified an extensive set of interactions between partners aimed at transferring scientific knowledge to businesses (Rosenberg & Nelson, 1994; Mansfield and Lee, 1996; Argyres and Liebeskind, 1998). In particular, relationship-based mechanisms are a specific mode of inter-organizational cooperation orientated to pursue an R&D assignment together with or without a commercial orientation (Hall et al., 2003; Arranz & Fdez de Arroyabe, 2008; Belderbos et al., 2015).

U–I relationships include a broad type of formal agreement such as collaborative research, joint R&D, contract research, and consulting (Perkmann & Walsh, 2007). The relevance of these relationships is mirrored by the fact that they represent one of the most frequent policy instruments put in place by policymakers to foster firms' innovation (Barajas et al., 2012). The effects of these relationships have been widely analysed at different levels (Jaffe, 1989; Adams, 2002; Boschma, 2005), and they are an important part of the foundations of evolutionary growth theories based on innovation models (Etzkowitz & Leydesdorff, 2000; Leydesdorff, 2012).

But, for macro-economic effects to be generated, collaboration between companies and universities has to be successful at an organizational level (Grillitsch & Trippl, 2018; Grillitsch et al., 2019). Most academic literature and practical guides tend to point to the existence of a positive impact on firms' performance (OCDE, 2018). However, primary studies, in their attempt to investigate the existence of a causal relationship between U–I collaboration and company's results, yield conflicting findings. U–I are found to impact positively on firm's performance; to have no effect at all, or even to produce a negative impact. All three possible research outcomes are well-reported in the literature. This paper aims to shed light on this topic by doing the first meta-regression analysis (MRA) of the quantitative microeconomic literature on the impact of U–I relationships on firms' performance. So, in line with meta-regression studies of other innovation topics (Dimos & Pugh, 2016; Neves & Sequeira, 2018; Ugur et al., 2020), we investigate this literature to determine the extent to which heterogeneous findings can be explained by the heterogeneity of samples and empirical methodologies. The degree—if any—to which this literature suffers from publication selection bias, and the genuine representative effect—if any—established by this literature— after controlling for possible publication bias and sources of heterogeneity on average—and firms' technical and economic specific performance measures—will likewise be investigated.

Our results show that the main variables which explain the heterogeneity and estimated effect size of the primary estimates are: the types of output measurements, research partners, relationships, and firms' sample and estimation characteristics. They also point out the existence of publication bias and, on average, a small positive effect on firms' performance after accommodating and correcting for publication bias. Furthermore, our research revealed that there is a verifiable medium-size effect on patent generation and a small negative effect on innovative sales growth.

This chapter has been organized as follows: In Section 3.2, we dissect the theoretical framework of the U–I relationship and the main causes of heterogeneity in their results; in Section 3.3, we explain the methodology used; in Section 3.4, we present the results obtained from the literature search and for the MRA; in Section 3.5, we discuss the implications of these results; and finally, in Section 3.6, we present the main conclusions, limitations of our work, and our future lines of research.

3.2. Theoretical framework and heterogeneity causes

In the previous decade, Perkmann & Walsh (2007) pointed out that to offer a general conclusion about U–I relationships is difficult due to the wide variety of analyses in terms of outputs, partners, contractual arrangements, and firms involved. Since then, several literature reviews have tried to provide a general conclusion (Vivas & Barge-Gil, 2015; Mascarenhas et al., 2018; Sjoo & Hellstrom, 2019; Skute et al., 2019). However, none of them has offered a quantitative estimation of the impact of the U–I relationship on firms' performance as reported in the literature. Thus, their conclusions have to be interpreted with caution.

In this section, we first review the theoretical framework behind the U–I relationships focusing on the motivations of firms to engage in this type of relationship. Second, we analysed different factors which the literature has pointed to as the main causes of heterogeneity in the reported effects of U–I relationships' impact on firms' performance. This enables us to identify a group of studies within the heterogeneous literature that are sufficiently homogeneous for valid investigation by MRA. We focus our analysis on types of output measurements, research partners, relationships, and firms

3.2.1. Theoretical framework

During the lasts 25 years, universities and other types of research and technology organizations (RTOs) have orientated the greater part of their efforts on their "third mission" (Mansfield,1995; D'Este & Patel, 2007). This third mission seeks the generation and transmission of knowledge outside academics to increase social-economic development based on technology and knowledge spillovers (Hall et al., 2003). One of the most-used mechanisms to achieve this goal is the collaboration between universities and industry on R&D projects (Beise and Stahl 1999; Adams et al., 2003). In the past, firms did R&D in-house; they only had contact with the universities during the recruitment process (Perkmann & Walsh, 2007).

However, as the importance of introducing new technical product and process increases to firms' results grew, the relationship between firms and research partners also grew (Nieto & Santamaría, 2010). Today there is a vast panoply of U–I relationships (Perkmann & Walsh, 2007). Different types of firms (e.g., High-Techs and SMEs (Small and Medium Enterprises)) collaborate with different types of research partners (e.g., Universities and Research institutes (RIs)) searching for different results (e.g., patents and productivity growth) under several types of relationships (e.g., joint R&D projects and outsourcing). But, through all of them, firms pursue the generation of a competitive advantage over their competitors (Philbin, 2008).

From an economic perspective, U–I relationships have been explained through the lens of transaction cost theory (Williamson, 1981). Transaction cost theory assumes that firms' 'make versus buy' decisions are driven by their willingness to reduce both production and transaction costs while protecting from opportunistic behaviour (Hagedoorn et al., 2000). Specifically, relationships with the university are seen as one of the leading ways to avoid the high cost of internalizing intangible assets (Hall et al., 2003), scientific personnel (Perkmann et al., 2013), and R&D facilities (Becker & Dietz, 2004). The cost reduction of the technological advance knowledge can have a direct effect on firms' results, increasing efficiency and financial results (Medda et al., 2004; Belderbos et al. 2006; Aschhoff & Schmidt, 2008). Moreover, by establishing formal relationships, both agents could avoid opportunistic behaviours focused on exploiting the knowledge (Vega-Jurado et al., 2009; Barge-Gil, 2010; Nieto & Santamaría, 2010).

From a strategic management perspective, these relationships have been explained through the resource-based view (Barney, 1991; Das & Teng, 2000) and stakeholder theory (Freeman & Reed, 1983; Siegel et al., 2003). The resource-based view considers that firms are boundlessly rational and undertake decisions based on the needs of their technological capabilities (Hall et al., 2003). Through relationships with universities, firms can access complementary resources and knowledge, use collaboration as a learning vehicle to accumulate and deploy new skills and capabilities, share R&D cost and generate the opportunity to develop innovations to satisfy market failures.

From the stakeholder perspective, firms' engagement with universities could be regarded as a CSR practice (Christensen et al., 2020). Universities and firms strive to satisfy social needs, and their cooperation in this respect can improve the level of economic development in a region, of innovation, and of educational development in society (e.g., promoting R&D joint project orientated to responsible research and innovation). Taking these advantages of the opportunities proposed by both strategic management perspectives, firms could develop a range of competencies and capabilities that lets them be more competitive in the market than their competitors (Arvanitis et al., 2008; Fey & Birkinshaw, 2005; Di Maria et al., 2019).

Both theoretical approaches claim that the existence of positive effects at firm-level empirical literature has shown contradictory results. For example, some authors, such as Arvanitis & Woerter (2009), who analysed a sample of 2,428 Swiss firms, found that consulting R&D activities has a positive impact on firms' patent generation and innovative sales. Howells et al. (2012) found a positive relationship between cooperation with higher education institutions (HEIs) and the introduction of innovation and firms' innovative sales revenue, in a sample of 371 UK firms. Furthermore, Medda et al. (2004) showed in a sample of 2,222 Italian firms how collaborative research with RIs has a positive effect on firms' productivity.

However, the same work showed how collaborative research also has a negative effect on firms' innovative sales. Others, like Kanama & Nishikawa (2017), who examined 1,001 Japanese manufacturing firms, found the same results. Access to university knowledge could increase firm innovation, but it is unlikely to result in profitable innovation. Furthermore, Tsai & Hsieh (2009), who analysed a sample of 1,346 Chinese manufacturing firms, found that joint R&D with RTOs has negative results on innovative product sales. These authors explain that the relationship between both agents could suffer different types of dissimilarities such as operational (i.e., organizational procedures) and cultural ones (i.e., goals and objectives) (Sarkar et al., 2001).

All the above-mentioned studies analysed UIR (University-Industry Relationships), although they address it from different perspectives. That is what other quantitative works and previous literature reviews have pointed out as the cause of the heterogeneity of results (Perkmann & Walsh, 2007; Vivas & Barge-Gil, 2015; Mascarenhas et al., 2018; Sjöö & Hellström, 2019; Skute et al., 2019). Specifically, they have pointed out the differences in the main characteristics of every U–I relationship: the output analysed, the research partner involved, the type of relationship, and the firm involved. We will use this same framework to address in detail the heterogeneity of results reported in the literature based on these characteristics.

3.2.2. Types of output measurements

Different types of measurement could find the result of the same U-I relationship fruitful for both parts, only for one, or negative for both (Perkmann & Walsh, 2007). However, one of the companies' main motivation for engaging university-industry collaboration is to use it as a "window" of scientific knowledge rather than for developing marketable innovations (Caloghirou et al., 2001; Volpi, 2017). In recent times, this trend has changed due to the need for both partners to increase the finalisation degree of collaborative projects (Zapp & Powell, 2017).

For universities, the evolution of performance-based research-funding systems (e.g., UK REF or Nordic FOKUS) increased the need to measure their impact on society as with, for example, measuring patent generation (Bellucci & Pennacchio, 2016; Hicks, 2012). For firms, the need to improve financial and economic results has increased the orientation towards developing innovations from science-based relationships, for example, developing new-to-market products (Faems et al., 2005; Parrilli & Alcalde-Heras, 2016). That is why it is important to take into account how the literature has measured the output of the U-I relationship. Based on Barge-Gil & Modrego (2011)'s work, it can be addressed from technical and economic perspectives.

Technical outputs consider the generation of any type of short-term output capable of being considered an innovation. This measurement includes new products and processes (Becker & Dietz, 2004; Fey & Birkinshaw, 2005; Nieto & Santamaría, 2010), and patents (Arranz & Fdez. de Arroyabe, 2008; Fabrizio, 2009; Hall et al., 2017). Most of the innovation literature tends to accept the positive effect of this type of formal collaboration on these outcome indicators (Arranz & Fdez. de Arroyabe, 2008; Arvanitis & Woerter, 2009; Nieto & Santamaría, 2010). For example, Nieto & Santamaría (2010) found a positive association between U-I cooperation and product innovation in Spanish firms. The literature which found a negative impact is residual (Adams et al., 2003; Fabrizio, 2009). However, there exists a sample of studies which do not find strong evidence in one direction or another (Arvanitis et al., 2008; Barge-Gil, 2010; Fey & Birkinshaw, 2005).

Economic output considers the impact of medium- to long-term effects on economic results, measured by total sales growth (Barge-Gil & Modrego, 2011; Di Maria et al., 2019; Fu & Li, 2016), sales growth of new products (Arranz & Fdez. de Arroyabe, 2008; Belderbos et al., 2004; Frenz & Ietto-Gillies, 2009), and added value or productivity growth (Aschhoff & Schmidt, 2008; Belderbos et al., 2006, 2004; Harris et al., 2013). The consensus on the effect on these outcomes is weaker in comparison with the technical outcome. Some studies found a positive impact (Arranz & Fdez. de Arroyabe, 2008; Aschhoff & Schmidt, 2008; Belderbos et al., 2004). However, others, such as Tsai & Hsieh (2009) found a negative association between the U-I relationship and the share of new-to-market innovative product sales and improved products in Taiwanese firms (Hall et al., 2003; Kanama & Nishikawa, 2017). Besides, the literature which points to non-clear evidence is larger (Belderbos et al., 2006, 2015; Frenz & Ietto-Gillies, 2009).

3.2.3. Types of research partners

In the U-I relationships, the "University" includes the traditional view of "Academia", but also encompass other types of modern research organisations, such as research institutes and public or private research centres (Vivas & Barge-Gil, 2015). Although all these research partners pursue the same objective of increasing the scientific and technological stock of knowledge of society (Jaffe, 1989), they could address society in different forms. Different types of research partners could influence the result of the UIR so as to be patent-orientated or to develop product or process innovations (Yaşar & Paul, 2012). As (Perkmann & Walsh, 2007) reviewed, under the "university" or "research partners", there are three main types of organisations: Higher Education Institutions (HEIs), Research Institutes (RIs) and Research and Technology Organizations (RTOs).

Higher Education Institutions (HEIs) refer to the traditional meaning of universities. These institutions play various roles in innovation systems (Teirlinck & Spithoven, 2012). Such roles include the education of students, advances in the limits of the frontiers of knowledge and collaboration with society, known as the "third-mission". In the last decade, this third role has gained much relevance (Hou et al., 2019). Higher Education Institutions can be orientated to collaborate in creating new knowledge but also to consult and guide in the introduction of innovations related to new materials and technologies for reducing energy and materials waste (Aiello et al., 2019; Albahari et al., 2017; Biedenbach et al., 2018). For example, Biedenbach et al. (2018) found a positive association between U-I cooperation and product and process innovation in a sample of Swedish firms. The literature which found a negative impact is residual (Fabrizio, 2009). However, there is a sample of studies which does not find strong evidence in one direction or another (Arvanitis et al., 2008; Barge-Gil, 2010; Fey & Birkinshaw, 2005).

Research Institutes (RIs) can carry out activities mostly related to applied scientific knowledge for developing innovations or patents (Hall et al., 2003). That is due to the fact that RIs' funds come from private sources related to a specific industry (Huang & Yu, 2011; Yaşar & Paul, 2012) or from public administration, which understands the need to establish strong research relationships between these organisations and companies. Furthermore, the objectives of these organisations are often project-oriented (Adams et al., 2003) and related to new scientific fields such as microelectronics, biotechnology and materials science (Hou et al., 2019). For example, Hou et al. (2019) find a positive impact of this partner on Chinese firms' new-product-sales revenue per employee. The literature which analyses this partner is smaller than previous categories, and its effect is not clear (Arvanitis et al., 2008; Brouwer & Kleinknecht, 1996; Medda et al., 2004).

Finally, other scholars have referred to the organisations above and to other types (e.g., public-private labs, public research organisations) under the term:

Research and Technology Organizations (RTOs). Scholars using this category do that because they consider that the common objective of increasing the scientific and technological stock of knowledge of society is enough to treat them as the same type of research partner. That is why this is the leading category used in the literature (Becker & Dietz, 2004; Belderbos et al., 2004; Robin & Schubert, 2013), and the results are contradictory. Some of them found positive results (Belderbos et al., 2015; Brouwer & Kleinknecht, 1996). In contrast, others addressed negative results or non-significant results with this type of partner (Nuñez-Sánchez et al., 2012; Barge-Gil & Modrego, 2011; Vega-Jurado et al., 2009).

3.2.4. Types of U-I relationships

One of the main types of U-I collaboration is the inter-organisational agreements which imply formal relationships such as research partnerships, contract research and consulting. On an organisational level, this type of cooperation can be motivated to reduce transactional costs of scientific knowledge and to use it as sources of competitive advantage (Lai & Chang, 2010). Perkmann & Walsh (2007) pointed out that firms value these relationships over the whole innovation cycle, not only for the initial supply of scientific knowledge and inventions. However, in some cases, research partnerships or collaborative research are more orientated to basic research than consulting or contract research. Based on the degree to which the inter-organisation is orientated to obtain a specific output, two types of contractual forms can be established: research partnership and service research.

Research Partnership includes collaborative research and joint-research ventures between universities and firms. This type of collaboration is usually conditional on public funding, but it could also be funded by private institutions (Adams et al., 2003; Caloffi et al., 2018). This relationship is the most complex since it implies that both types of organisations pool their R&D resources, infrastructures and personnel in a form of joint work to achieve the general objectives of the project, as well as the specific goals of both organisations (Fabrizio, 2009). Using firm-level evidence, Radicic & Pinto (2019) find a positive effect on product and process-innovation in Spanish low- and medium-low- technology industries, although others like Medda et al. (2004) do not find strong evidence of positive returns on collaborative research with universities in enhancing productivity in Italian firms.

Service Research implies an externalisation of the company's R&D activities in the facilities and laboratories of the research organisation (Darby et al., 2004; Hou et al., 2019) and consulting activities (Arvanitis & Woerter, 2009; Brouwer & Kleinknecht, 1996). The relationship could be less complicated than research partnerships, since it is not necessary to combine resources, but rather establish a contractual relationship which is linked to achieving the objectives set by the company that is financing the project. Moreover, consulting implies a formal agreement based on the possibility of the university advising the company on R&D activities for new products (Perkmann & Walsh, 2007). Consulting usually happens in the initial stages of launching new products or implementing new organisational processes in a company (Brouwer & Kleinknecht, 1996; Arvanitis & Woerter, 2009, Di Maria et al., 2019). In this case, the collaboration can be more flexible and developed in different ways, always based on mutual adaptation. On an organisational level, some authors like Grimpe & Kaiser (2010) find a positive relationship between R&D outsourcing and German firms' innovative performance.

3.2.5. Types of firms

Since Laursen & Salter (2004)'s works some part of the scholar's studies have focussed on what types of firms may benefit more from a relationship with research partners. Some of them have analysed firms' internal resources and capabilities (Escribano et al., 2009; Grimpe & Kaiser, 2010), while others have focussed on the environment in which the UIR is developed (Buerger et al., 2012; Caloffi et al., 2020). However, the most important topic could be the firms' attributes; this research topic has been addressed from two main perspectives: the industrial perspective, focussing on high-tech companies (Hall et al., 2003; Kim, 2012), and manufacturing firms (Becker & Dietz, 2004; Hewitt-Dundas et al., 2019), and from a Schumpeterian approach, focussing on small and more dynamic firms (Belderbos et al., 2006; Hewitt-Dundas et al., 2019; Neyens et al., 2010), and those which are innovative because they have developed R&D activities and innovative routines (Barge-Gil, 2010; Yu & Lee, 2017).

Companies based on high technologies include aerospace, software, and biotech firms, among others (OCDE, 2018). These firms tend to be knowledge-intensive (Cosh & Hughes, 2010), and due to this, the relationship with universities can be essential for high-tech firms to overcome their constraints and boost innovation and patent generation. Specifically, the relationship between research organisations and biotech companies has been deeply analysed (Fabrizio, 2009; Hall et al., 2003; Wang et al., 2013). However, the effects of collaboration between this type of firm and universities are not clear. For example, Kim (2012) does not find a positive influence on the developing of new products in a sample of US biotech firms.

Sector and industry differences have also been taken into account in the literature as control variables (Aschhoff & Schmidt, 2008; Belderbos et al., 2015). However, other studies delve deeper into the differences between specific sectors (Ukpabio et al., 2016). The main classification done here is between manufacturing and service firms (Becker & Dietz, 2004; Belderbos et al., 2004; Hewitt-Dundas et al., 2019). Manufacturing firms orientate their collaboration to introduce new products or techniques which increase economic results and productivity. For example, Zhang et al. (2019) find a positive relationship between U-I relationships and innovation in a sample of listed Chinese manufacturing firms.

Since Schumpeter's work (Malerba & Orsenigo, 1996), firm size has also been an important topic in the discussions of what firms innovate (Cohen, 2010). Some researchers have focussed their analyses on the SME firms, which can be more innovative due to their capacity to assimilate new knowledge and routines faster (Belderbos et al., 2006; Hewitt-Dundas et al., 2019; Neyens et al., 2010). For example, Nieto & Santamaría (2010) find a more positive interaction between small companies and Spanish manufacturing firms than the effect produced in technological collaboration in medium and big firms. However, Neyens et al. (2010) found non-significant results in a sample of 217 German firms.

Finally, the consideration of "innovative firms" as also been studied (Cohen, 2010). These firms are those which develop R&D activities and those which introduce a kind of innovation, and are the most studied category. Innovation Surveys have created a vast amount of data regarding this type of firm (Hong et al., 2012). The scholars argue that this type of firm could suffer fewer operational dissimilarities with research partners and would obtain better results than others. Some studies, such as Inauen & Schenker-Wicki (2011), find a positive causality between university collaboration and product innovation in a sample of stock-listed companies from Germany, Switzerland and Austria. However, others do not find positive results (Barge-Gil, 2010; Yu & Lee, 2017).

3.3. Methodology

3.3.1. Data collection and literature search

First, adapting Perkmann & Walsh (2007) and Vivas & Barge-Gil (2015)'s search protocols, we started establishing a group of keywords that were representative of the main concepts used in the previous literature. The chosen keywords were grouped into five categories, presented (see Appendix, Table 3.A). The first category was used for grouping keywords referring to universities and research partners (University). The second category contains collected terminology for firms (Industry). The third group included terms to describe the collaboration (Collaboration). The fourth group collected keywords addressing the type of interaction (Relationship). The fifth and final group collected keyword terminology for impact evaluation of performance (Impact).

Second, we chose the Web of Knowledge and Scopus databases for this review. The first search string returned a total of 16,891 publications from both databases. The list of publications was then narrowed to those articles (both published and unpublished but available before our cut-off date of 26 November 2019) related to social science and science and technology areas (see Appendix, Table 3.B) in which the evaluation of U-I relationships could be analysed from our same perspective. The total number decreased to 5,954, results after duplicates were removed. This is a considerable number of documents, the main explanation for it being that the keyword "University" covers a vast number of topics. (For comparison, Vivas & Barge-Gil (2015) obtain similar results). So, we did a screening process to include only those studies which analyse the quantitative evidence of the impact of the U-I relationship on firms' performance.

Accordingly, we established exclusion criteria based on the limitation of the MRA analysis: (1) the article must use empirical quantitative regressive methods (semi-parametric and non-parametric approaches were excluded), (2) the effect must be analyses from the firm's output perspective (analyses of inputs or pure spillovers were excluded), and (3) there must be an inter-organisational agreement (informal relationships were excluded).

Finally, the dataset consisted of 173 estimates from 51 studies directly related to University-Industry relationships, featuring results and data, and examining a measure of firm performance. The studies are listed and summarised in see Appendix Table 3.C. Finally, to achieve the highest standards demanded of scientific rigour, we contrasted our final set with the sets of Vivas & Barge-Gil (2015) and Perkmann & Walsh (2007). We corroborate that all papers listed in their analyses address our inclusion criteria.

3.3.2. Coding Methodology

In order to develop a Meta-Regression Analysis (Stanley & Doucouliagos, 2012; Stanley et al., 2013), we needed to quantify and classify the relevant information from each study. We recorded the following article information: author's name, year, title, method of data collection, effect size of interest and standard error (based the author's report), number of observations, time period that the analysis involved, country in which the observations were studied, type of collaboration, partner and outcome, among other studies' main characteristics –see Table 3.4. for the complete list of the studies' coding dimensions–.

3.3.3. Conversion to a common effect size

As pointed out in the background theory, there are specific characteristics of the U-I studies which could influence the output. Moreover, the existence of different measures for each type of impact complicates the analysis because although they are related, they are not equal. However, a similar problem has already been overcome by Stanley & Doucouliagos (2012). These authors recommend converting each estimated coefficient to the partial correlation coefficient as a standard metric. This enabled us to compare the connection between U-I relationship and firm performance through different specifications and alternative measures. To include as many estimations as possible, U-I relationship impact on firm performance was measured via the partial correlation-coefficient.

Partial correlation-coefficient (PCC) is a unit-free measure of the magnitude and direction of the association between an independent variable over a dependent variable, arrived at by holding others included in the model constant (Dimos & Pugh, 2016). In this case, we used them to isolate the effect of U-I relationship on the firm's performance. Using PCC in MRA has several advantages compared with other potential-effect size measures such as correlations or Fisher's Z-transformation (Stanley et al., 2018). Partial correlation-coefficient and its standard error calculation formula are detailed in Equation 3.1 and Equation 3.2:

Equation 3.1 $PCC_i = t/\sqrt{(t^2 + df)}$

Equation 3.2 $SEpcc_i = \sqrt{(1 - PCC^2/df}$

Where *t* stands for the t-statistic on the estimated U-I relationship effect and *df* for the degrees of freedom extracted from the respective estimate in the primary literature.

3.4. Results

3.4.1. Characteristics of included studies

In order to ascertain the main attributes of the studies analysed, we account for the study's publishing year, journals and countries, and the specific characteristic of the U-I relationships.

A descriptive analysis of our results shows us that half of the studies were published after 2011. The literature suffers a reduction in number of papers in the period of 2013-2016; however, in the last year of the decade, this relationship grabbed the attention of academics and practitioners as the role of science-driven innovation had become a key concern for firms' performance. Furthermore, the three most interesting journals dealing with this relationship are *Research Policy*

(15.69% of the studies), *Technology Transfer* (15.69%), and *International Journal of Technology Management* (7.84%). To determine countries with the most research regarding U-I collaboration, a simple counting of papers was conducted. The most-analysed countries are Spain (23.52%), the USA (13.73%) and Germany (13.73%).

As we reported in the theoretical discussion, there is a natural difference between the different characteristics of U-I relationships which are the cause of the heterogeneity. Focusing on the output measurement, we differentiated between *technical outcome* (67.63% of the observations), which includes the studies which measure this impact in terms of product or process innovation and patent generation, and *economic outcome* (32.37% of the observations), which includes studies which analysed the increase in sales, innovative product sales, and the firm's added value or productivity. The classification based on the types of relationships was between *research partnerships* (88.44%) and *service research* (11.56%). The former includes joint R&D and cooperation agreements, the latter, contract or outsourcing research inter-organisations. The final category was based on the types of research partners. We differentiate between *research and technology organisations* (43.35% of the observations), which is the most used category because it does not distinguish between *Higher Education Institutes* (47.40%) and *Research Institutes* (9.25%).

3.4.2. Meta-regression analysis

In this section, we first measure the existence of a real effect between U-I relationships using the weighted averages of the estimated results. Second, we study the degree of a potential publication selection bias through the FAT-PET-PEESE approach. Third, an estimation of the real effect of U-I relationships on the new patent generation and innovative sales growth is made. Finally, the sources of heterogeneity effect size established by this literature after controlling for possible publication bias are evaluated.

3.4.2.1. Basic MRA

Beginning with our meta-analysis, Table 3.1 shows overall weighted averages of partial correlation-coefficients of the U-I relationship effect on firm performance.

The inverse of its variance weights each PCC. The fixed effect estimates (FEE) weights each effect estimation by the inverse of its squared standard error ($1/SE_i^2$). The random effect estimates (REE) use more complex weights that allow for excess between-study heterogeneity (τ^2), as well as individual estimation error ($1/(SE_i^2 + \tau^2)$). However, according to Stanley & Doucouliagos (2015), the FEE and REE estimator provides estimates inferior to unrestricted weighted least square (WLS), especially when there is publication selection bias and heterogeneity, as here.

Table 3.1. Unweighted and weighted averages of PCCs

	(1) FEE	(2) REE	(3) WLS
Average	0.024	0.041	0.024
95% CI	0.022 to 0.027	0.033 to 0.050	0.17 to 0.031
N	173	173	173
k	51	51	51

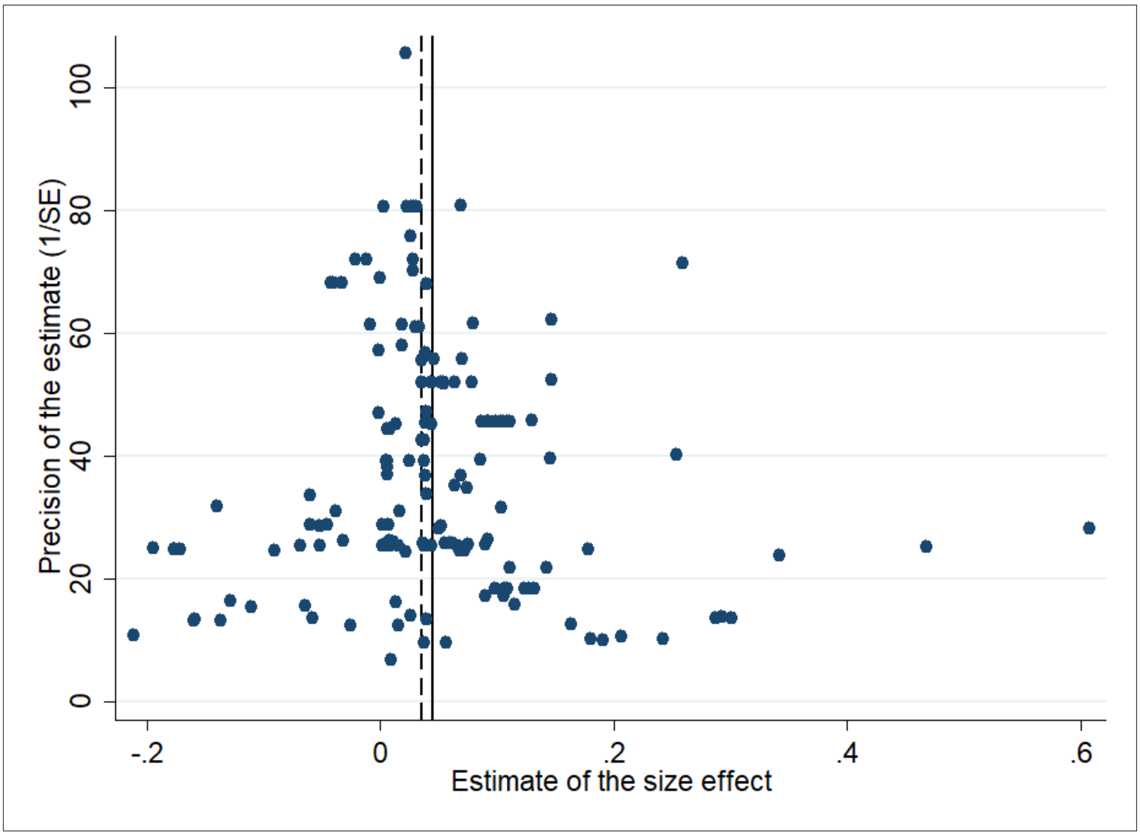
Notes: Columns (1-3) report the overall weighted average for partial correlations coefficients. FEE, REE and WLS denote fixed effects, random effects and unrestricted weighted least squares, respectively. N is the number of estimates. k is the number of studies. Source: Own elaboration

In Table 3.1, average estimates of the PCCs are reported; all of them are greater than zero. Analysing WLS results, it appears that the partial correlation between U-I relationship and firm performance is 0.024. As per Doucouliagos (2011), economic guidelines for assessing the strength of a correlation coefficient, U-I collaboration, have a small effect on firm performance. This effect size could be a result of the non-existence of a real impact, or due to the existence of heterogeneity. The Cochrane's Q-test indicates clear evidence of excess heterogeneity beyond what is measured by random sampling alone ($p < 0.001$). To account for this heterogeneity, we identify a group of moderator variables, in the relationship between U-I cooperation and firm performance, which can produce it (see Table 3.4). However, before we turn to analysing them through a multiple meta-regression, we need to explore whether there is publication selection bias and how it might affect the reported output estimates in the literature.

3.4.3. Publication selection bias

Publication bias occurs whenever the research that appears in the published literature is systematically unrepresentative of the population of completed studies (Rothstein et al., 2006). It can be the result of a specification search to obtain estimates of a particular sign or – especially in small sample studies – to get more significant estimates to offset more significant standard errors. The usual way to analyse the existence of publication bias is through a funnel graph (Schmidt & Hunter, 2015).

Figure 3.1. Funnel Plot, Partial Correlations of U-I Relationship impact



Source: Own elaboration

Figure 3.1 shows a funnel graph of the effect of U-I collaboration on firms' performances. On the horizontal axis, the estimated effect derived from each study's partial correlation coefficient is displayed; and on the vertical axis, the precision of the estimate measured by the inverse of its standard error. More precise estimates will be close to the real underlying effect, while the imprecise estimates will be more dispersed at the bottom of the figure. Therefore, in the absence of publication selection, the figure should resemble a symmetrical inverted funnel plot. The dashed line represents the median and the solid the average reported effect. A visual inspection of Figure 3.1 suggests an imbalance in the reported impact of U-I relationships, as the right side of the funnel appears to be heavier. This finding indicates that positive estimates above zero may be preferably selected in the published studies.

However, visual methods are subjective, so we test for publication bias statistically. To carry out this test, we follow an approach well-known in the meta-analysis literature, namely the basic meta-regression or Egger's regression (Equation 3.3) (Egger et al., 1997; Schmidt & Hunter, 2015; Stanley & Doucouliagos, 2012).

Equation 3.3 $$r_i = \alpha_0 + \alpha_i SE_i + \varepsilon_i$$

Where r_i is the estimated effect (in this case, partial correlation-coefficient), SE_i is its standard error, and εi the conventional random sampling (or estimation) error. The term α_i is used to test for publication bias.

Through this regression, we contrast two hypotheses. First, the null hypothesis that $\alpha_1=0$: this test provides statistical evidence whether or not there is any publication selection bias and is known as the funnel asymmetry test, or "FAT". Second, Egger's Regression also tests the null hypothesis that $\alpha_0=0$: this test identifies whether there is any underlying empirical effect remaining after potential publication, and is known as the Precision Effect Test, "PET".

If the PET fails to reject the null hypothesis of no effect, then $\alpha 0$ is taken as the estimate of overall effect with the understanding that it is statistically insignificant from zero. If the PET rejects the null, then a new specification is estimated, and the associated estimate of γ_0 represents the best estimate of the overall effect, known as the Precision Effect Estimate with Standard Error, PEESE test. (Stanley & Doucouliagos, 2012; Alinaghi & Reed, 2018). According to Stanley et al. (2018), instead of using the standard error of the PEESE test, we use the variance of the estimated coefficient (SE_i^2), which gives a better estimate of the size of the genuine effect, corrected for publication bias (Equation 3.4).

Equation 3.4 $$r_i = \gamma_0 + \gamma_i SE_i^2 + v_i$$

The FAT-PET-PEESE model for Partial Correlation Coefficients of all 173 estimates is reported in Table 3.2. Columns 1-2 reports use FAT-PET using unrestricted the WLS approach. As stated before, we preferred this approach rather than FEE or REE, because both meta-regression models (1) and (2) suffer heteroskedasticity resulting from the reported effects' widely different standard errors. MRA regression coefficients from the unrestricted WLS-MRA models can be used to test for the presence of publication selection bias (H_0: α_1=0), and a genuine effect beyond publication selection bias (H_0: α_0=0). However, due to several estimates reported by most studies and in order to offer a robust analysis, we also report results corrected for potential within-study-dependence as well as calculated robust standard errors (column 5-6).

Table 3.2. FAT-PET-PEESE results

	(1) FAT (α_1=0) WLS	(2) PET (α_0=0) WLS	(3) PEESE (γ_0=0) WLS	(4) FAT (α_1=0) Cluster Robust	(5) PET (α_0=0) Cluster Robust
Coef.	1.083***	0.013**	0.022***	1.083*	0.012
95% CI	0.386 to 1.780	0.003 to 0.023	−0.740 to 2.520	-0.897 to 2.255	-0.008 to 0.033
t-value	3.07	2.40	5.56	1.85	1.24

Notes: The dependent variable is partial correlations. *Coef.* is the estimated coefficient. 95% *CI* offers the interval confidence at 95%. t-*value* is the t-statistic of the estimate. FAT-PET Estimates (columns 1-2 and 4-5) are based in Eq. 4 using unrestricted weighted least squares (columns 1-2) and cluster-robust standard errors (columns 4-5). PEESE Estimate (column 3) are based in Eq. 5 using unrestricted weighted least squares. FAT tests the presence of publication selection bias, PET and PEESE estimates and tests the effect of U-I relationship on firm's performance corrected for publication selection bias. *p < 0.1; **p < 0.05; ***p < 0.01. Source: Own elaboration.

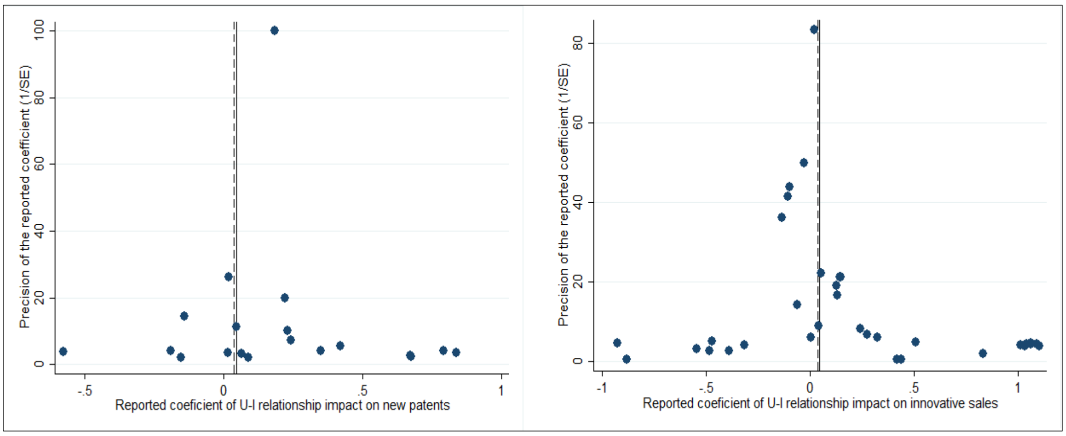
It must be noted that estimates provide evidence of publication bias ($\hat{\alpha}_1$=1.083). However, there is a possibility that this bias is due to other moderating factors (e.g., study characteristics and sample characteristics). Besides, as a result of the rejection of the null hypothesis ($\hat{\alpha}_0$=0.013), we can assume there is clear evidence of a positive effect of U-I collaboration on firms' performance: a PEESE test confirms this effect ($\hat{\alpha}_0$=0.022).

However, according to Stanley & Doucouliagos (2014), these analyses show that the U-I relationships have a small-size effect on firms' performance, so we will analyse two subsamples to address specific effect size on different outcomes and, after that, account for other explanatory variables which can be a source of heterogeneity.

3.4.4. Patents and innovative sales as effect size

To gain further insight into the size of the U-I relationship effect on firms' performance, we analyse the impact of the collaboration in technical and economic subsamples as well as the implications for patent generation (28 observations) and innovative sales growth (44 observations). The former is selected as the representative for technical outcome and the latter for an economic one. Using these comparable dependent variables between primary studies, we analyse the effect size without primary studies of both subsamples are plotted against their inverse standard error in Figure 3.2.

Figure 3.2. Funnel Plot, Reported coefficients of U-I relationship impact



Source: Own elaboration

To check for the existence of a real effect on patent generation and innovative sales, we use the FAT-PET-PEESE approach by estimating Eq. 3-4. Here, *r* stands for the coefficient reported in the literature and SE_i for its standard error. In this model, the estimated size directly gives the impact representative of each subsample. Table 3.3 reports the estimates.

Compared to the full-sample estimates for effect estimates reported in Table 3.2, these subsample estimates of the FAT test provide weaker evidence of publication bias on patent subsample and a relatively high bias regarding the innovative sales subsamples. Moreover, in Table 3.2 the estimated impact of U-I cooperation on firm's performances was lower compared to the one reported on patent generation in Table 3.3 ($\hat{\alpha}$=0.153) and higher compared to the impact on innovative sales ($\hat{\alpha}$=-0.055). PET and PEESE estimations let us conclude the existence of the robust real medium-size effect of U-I collaboration on firms' patent generation and a negative or non-significant effect on the sales growth of innovative products.

Table 3.3. FAT-PET-PEESE. Patents and innovative sales effect sizes

	FAT (α_1=0) WLS	PET (α_0=0) WLS	PEESE (γ_0=0) WLS	FAT (α_1=0) Clust. Robust	PET (α_0=0) Clust. Robust
New	0.907*	0.153***	0.170***	0.907	0.153***
Patents	[-0.160;1.975]	[0.100;0.204]	[0.134;0.206]	[-1.211;3.026]	[0.834;0.221]
(k=28)	*t*= 1.75	*t*= 6.01	*t*= 9.72	*t*= 0.95	*t*= 4.96
Inno. Sales	1.538***	-0.055**	-0.139	1.538	-0.055
(k=44)	[0.501;2.574]	[-0.105;-.006]	[-0.058;0.030]	[-0.869;3.944]	[-0.163;0.052]
	t= 2.99	*t*= -2.25	*t*= -0.63	*t*= 1.35	*t*= -1.09

Notes: The dependent variable is the reported coefficient by the primary study. The "New Patents" subsample is formed by 28 observations from 11 studies and the "Innovative Sales" subsample is formed by 44 observations from 17 studies. First the estimated coefficient is reported, between brackets are the interval confidence at 95% and finally, *t*= is the t-statistic of the estimate. FAT-PET Estimates (col. 1-2 and 4-5) are based in Eq. 4 using unrestricted weighted least squares (col. 1-2) and cluster-robust standard errors (columns 4-5). PEESE Estimate (col. 3) are based in Eq. 5 using unrestricted weighted least squares. FAT tests the presence of publication selection bias, PET and PEESE estimates and tests the effect of U-I relationship on firm's performance corrected for publication selection bias. *p < 0.1; **p < 0.05; ***p < 0.01. Source: Own elaboration.

3.4.5. Multiple MRA

Several researchers who analyse U-I relationships and firm's performances emphasise that the estimated effect depends on the study attributes such as output measure, data span, type of firms analysed and even information source (Perkmann & Walsh, 2007; Vivas & Barge-Gil, 2015). The characteristics of each study generate an intrinsic heterogeneity in our basic MRA. To determinate whether the research context influences the practical effect, we conducted a multivariate regression analysis. The hypothesised sources of this excess heterogeneity are incorporated into Equation 3.5 as "moderator variables", in order to obtain a better understanding of the variation of the estimated effects size. However, only those research dimensions present in at least five primary studies are specified in our MRA model, which can be expanded as follows:

Equation 3.5 $$r_i = \beta_0 + \sum\beta_k Z_{ki} + \beta_1 SE_i + \sum\delta_{ji} SE_i K_{ki} + \varepsilon_i$$

In this model (Equation 3.5), α_0 from Equation 3.3 is replaced by $\beta_0 + \beta_k Z_{ki}$ where the Z variables represent heterogeneity. The $SE_i K_{ki}$ terms constitute any factor related to publication bias or the researches' inclination to report a statistically significant positive U-I collaboration effect. The classification into Z- and K-variables is not exempt from the debate, as Dimos & Pugh (2016) and Valickova et al. (2015) point out; the classification done by Stanley & Doucouliagos (2012, p. 91) is to some degree arbitrary. Stanley et al. (2018) noticed that, and in recent articles, they relaxed their point of view, considering that some methodological study characteristics could be related to the publication bias.

We consider as Z-variables those related with the primary study characteristics like the type of U-I relationship studied or the methodological characteristics. These variables have a direct influence on the effect size, ceteris paribus. K-variables are those which address special attributes of the sample and not all the primary studies have focussed on them (types of firms: *Innovative*, *High Tech.*, *Manufacturing* and *SME*) and which we used as control variables - with caution (Dimos and Pugh, 2016: 808). Due to its relevance, we also consider whether the source of the data is the Community Innovation Survey or other CIS-based questionnaire as a K-moderator variable (*CIS Data*). Z- and K-variables could influence the research towards reporting a statistically significant positive effect due to "*a priori*" bias influence based on the sample characteristics or in "*posteriori*" bias due to the interest in publishing it. Table 3.4 lists all the Z/K moderators that are coded and investigated in this study. Specifically, we examined differences in the type of U-I relationship by means of dummy variables coded *Partnership Research* as the omitted variable in our MRA model. The second type of moderator variable concerned is the kind of research partner: *Research and Technology Organisations* category is used as the reference variable. The third type of moderator variable involved is related to the sort of impact. *Economic outcome* is used as the reference variable among other moderator variables driven by the parametric method, and regional effects are also taken into account.

Table 3.4. Variables, Z/K moderators, means and standard deviations

	Variable	Description	Z/K	Mean	SD
	PCC	is the Partial Correlation Coefficient of U-I collaboration and firm performance		0.044	0.104
	SEpcc	is the Standard Error of the estimated Partial Correlation		0.035	0.025
Type of Impact	*Technical Impact*	=1, if estimate comes from technical impact, 0 otherwise	Z	0.665	0.473
	Economic Impact	=1, if estimate comes from economic impact, 0 otherwise	Z	0.335	0.473
Type of Relationship	*Research Partnership*	=1, if estimate comes from U-I collaboration research, 0 otherwise	Z	0.884	0.321
	Service Research	=1, if estimate comes from U-I contract research, 0 otherwise	Z	0.116	0.321
Type of Research partner	*Higher Education Institution*	=1, if estimate uses data from a relationship with HEIs.	Z	0.474	0.501
	Research Institute	=1, if estimate uses data from a relationship with RIs, 0 otherwise	Z	0.092	0.291
	Research and Technology Org.	=1, if estimate uses data from a relationship with RTOs, 0 otherwise	Z	0.434	0.497
Regional effects	*European Union*	=1, if estimate uses data from European Union, 0 otherwise	Z	0.578	0.495
	USA	=1, if estimate uses data from United States of America, 0 otherwise	Z	0.127	0.334
	UK	=1, if estimate uses data from United Kingdom, 0 otherwise	Z	0.087	0.282
	China	=1, if estimate uses data from China, 0 otherwise	Z	0.162	0.369
	Japan	=1, if estimate uses data from Japan, 0 otherwise	Z	0.012	0.107
	South Korea	=1, if estimate uses data from South Korea, 0 otherwise	Z	0.023	0.151
Estimation characteristics	*Control Sector*	=1, if estimate controls for firm sector, 0 otherwise	Z	0.532	0.500
	Control Size	=1, if estimate controls for firm size, 0 otherwise	Z	0.555	0.498
	Control R&D	=1, if estimate controls for firm R&D activities, 0 otherwise	Z	0.711	0.455
	Control Age	=1, if estimate controls for firm age, 0 otherwise	Z	0.434	0.497
	Control Gov. Support	=1, if estimate controls for government supported projects, 0 otherwise	Z	0.035	0.184
	Homogenety	=1, if estimate comes from a homogeneity firm sample, 0 otherwise	Z	0.116	0.321
	Endogeneity	=1, if estimate controls for endogeneity problems, 0 otherwise	Z	0.081	0.274
	OLS	=1, if OLS method is used for the estimation, 0 otherwise	Z	0.445	0.498
	Probit	=1, if Probit method is used for the estimation, 0 otherwise	Z	0.179	0.385
	Logit	=1, if Logit method is used for the estimation, 0 otherwise	Z	0.145	0.353
	Other Methods	=1, if other methods are used for the estimation, 0 otherwise	Z	0.254	0.437
	Cross sectional	=1, if study uses cross sectional data to estimate, 0 otherwise	Z	0.474	0.501
	Panel	=1, if study uses panel data to estimate, 0 otherwise	Z	0.289	0.455
	Pooled Cross Sectional	=1, if study uses pooled cross-sectional data to estimate, 0 otherwise	Z	0.237	0.426
	Log	=1, if Log. transformation is applied for the dependent variable, 0 otherwise	Z	0.353	0.479
Type of Firms	*CIS Data*	=1 if estimate uses data from CIS based survey, 0 otherwise	Z/K	0.434	0.497
	Manufacturing Firms	=1 if estimate uses data from manufacturing firms only, 0 otherwise	Z/K	0.162	0.369
	High tech Firms	=1 if estimate uses data from high tech. sector firms only, 0 otherwise	Z/K	0.370	0.484
	Innovative Firms	=1 if estimate uses data from innovative firms only, 0 otherwise	Z/K	0.046	0.211
	SME Firms	=1 if estimate uses data from small or medium firms only, 0 otherwise	Z/K	0.162	0.369

Source: Own elaboration

According to Stanley et al. (2018), we follow the general-to-specific modelling approach in our model WLS-MRA (Columns 1-3), validated through a robust-standard estimation (Columns 2-4).

Table 3.5 shows the results of our WLS-MRA model for a holdout- (Columns 1-2) and a within-sample (Columns 2-4). This table presents the set of moderator variables that were included in the final sample of the general-to-specific model WLS approach.

We now focus on the previously analysed variables selected by the theoretical framework related to the collaboration characteristic. We show that there is a publication bias in the literature based on the outcome, the research partner and the type of relationship. *Technical outcome* (0.080) has a statistically significant positive effect. If we focus on the kind of research partner, we demonstrate that single collaboration with *HEIs* (-0.035) or *RIs* (-0.037) have a negative influence compared with the general group research and technology organisations. *Service Research* (0.044) is positive, significant in WLS estimation. Being cautious, we can assert that university consulting or contract research activity for firms has a positive effect (0.044) on firm performance compared with research partnerships.

Following Dimos & Pugh (2016), we also analyse the effect produced by the firm characteristic. This specific effect influences the partial correlation coefficient and even the publication bias. If primary studies samples are formed only by innovative firms (*Innovative Firms*, -0.025), the MRA-analysis shows a negative effect on the partial correlation coefficient. And, samples only formed by Manufacturing firms interact with the standard error SEppc (*Manufacturing Firms * Sepcc*, 0.038), resulting in authors having more possibility of publishing when they analyse this type of firm.

Moderator variables of regional effects are significant for *the European Union* and the *USA*. The former shows a positive impact (0.021) and the latter, a negative one (-0.031). Moderator variables of firm control such as *Age* (-0.039), *R&D activities* (-0.048) and *Sector* (-0.066), provide a small partial correlation effect which implies little practical value. In this estimation, only controlling for

Government support (0.066) has a positive impact on effect-size. In short, we can affirm that controlling for firms' age and R&D activities and industry has a negative practical value in the studies' regressions, and controlling for government support of the collaboration increased the partial correlation effect estimates.

Table 3.5. Multiple WLS-MRA of U-I Relations effects

Variables	Holdout sample		Within Sample	
	WLS	Cluster Robust	WLS	Cluster Robust
Technical output	0.080*** (0.011)	0.058*** (0.011)	0.116*** (0.016)	0.090*** (0.019)
Higher Education Institutions	-0.035*** (0.011)	-0.018** (0.008)	-0.048*** (0.012)	-0.021* (0.012)
Research Institutes	-0.037** (0.014)		-0.058*** (0.016)	-0.030* (0.015)
Service Research	0.044** (0.022)			
Innovative Firms	-0.025** (0.011)	-0.016* (0.009)	-0.021* (0.011)	
European Union	0.021* (0.011)			
USA	-0.031* (0.017)	-0.022* (0.011)	-0.053*** (0.015)	-0.042*** (0.013)
Control Age	-0.039*** (0.012)	-0.051*** (0.014)	-0.072*** (0.014)	-0.070*** (0.019)
Control R&D	-0.048*** (0.013)	-0.056*** (0.017)	-0.057*** (0.012)	-0.048*** (0.014)
Control Sector	-0.066*** (0.013)	-0.027** (0.012)	-0.048*** (0.010)	-0.037** (0.017)
Control Gov. Support	0.066* (0.034)			
Endogeneity	0.041*** (0.014)	0.027*** (0.009)		
Log	-0.038*** (0.014)	-0.041*** (0.015)	-0.046*** (0.012)	-0.047*** (0.013)
Logit	-0.031** (0.014)		-0.056*** (0.015)	-0.043* (0.024)
*Manufacturing Firms * SEpcc*	0.038*** (0.010)			
SEpcc	1.166*** (0.402)			
Intercept	0.048** (0.024)	0.104*** (0.018)	0.156*** (0.020)	0.142*** (0.036)
Number of observations	173		171	
Number of studies (clusters)	51		50	
R^2	0.491	0.418	0.518	0.503
AIC	-646.613	-644.012	-646.613	-644.012
BIC	-599.488	-603.171	-599.488	-603.171

Notes: The dependent variable is partial correlations coefficients. Standard errors are reported in parenthesis. See Table 2.4 for variable definitions. *p < 0.1; **p < 0.05; ***p < 0.01. Source: Own elaboration.

Moderator variables of the primary studies estimation method show that the primary studies control for Endogeneity has statistically significant positive effects (0.041). Based on this last result, we can assert that controlling for the endogeneity problem (i.e., mostly used lag variables) increases the U-I collaboration effect reported. Also, analysing the estimation method used in the primary studies, results show the *log* base (-0.038) has a significant adverse impact on the estimation as does also the use of the *Logit* (-0.038) estimation method.

Finally, our omission of Barge-Gil & Modrego (2011) provides an opportunity to see if our MRA model provides accurate predictive or explanatory ability. If a meta-regression model is genuinely explanatory, it captures some true relationship to the underlying effect investigated, which can be used to forecast future performance. Unfortunately, this is not the case for the multiple WLS-MRA model reported in column 1, Table 3.5. The mean absolute deviation (MAD) for the holdout sample of 51 studies of U-I collaboration on economic growth is 24% larger than the within-sample MAD (0.058 vs 0.047) and the RMSE is quite similar (0.036 vs 0.035). However, as the adjusted R^2 is near 0.50, the above results regarding the causes of heterogeneity should be interpreted cautiously.

3.5. Discussion

Our meta-regression analysis serves to review the reported effects of U-I relationship on firms' performance, analysing the parametric quantitative literature on the subject over the past quarter of the century. Our basic MRA and multiple MRA offer essential findings of the literature that need to be analysed carefully.

First, the analysis of the weighted average shows that the real effects of this collaboration on the company's performance are positive, though small. This effect has been statistically proven through the FAT-PET-PEESE approach. These tests confirm that there is a publication bias in the primary studies and that this heterogeneity in the reported effects should be deepened. Moreover, analysis of the effect size measured as new patent and innovative sales confirms that there is a real medium effect on companies' technical and negative or no significant impact on economic performance.

Second, an analysis of the causes of heterogeneity confirms that the works which analyse the relationship between Research and Technology Organisations and firms report more significant results than those which examine the relationship only with Higher Education Institutions or Research Institutes. The existence of a small number of papers in the sample that focus on RIs could be the cause of that negative effect. Even so, being cautious, we can interpret the variable that partially collects them as a proxy for the real impact generated by this type of organisation. RTO are more oriented towards applied science projects with market orientation (Teirlinck & Spithoven, 2012).

The idea, that primary works which analyse more finalisation-orientated relationships report higher results, is not accepted. Research Partnership has often been pointed out as difficult cooperation between two different cultures which can generate problems of adaptation. However, in modern times inter-organisational cooperation has solved these problems, establishing clear objectives (Estrada et al., 2016). Also, it should also be noted that innovative firms are often analysed as the main important firm partner. However, our results show that non-innovative firms could benefit the most, more than those which use the collaboration only as a window to scientific knowledge and scientific personal. collaborative outcomes are fully exploited by established companies and universities (Almeida et al., 2011).

3.6. Conclusions

The broad interest in U-I collaboration is understandable. Innovation literature is based on models that give this relationship a prominent place (Bozeman et al., 2013). However, none of the research yields unambiguous conclusions to the effect of U-I relationship on firms' performance. We conducted a meta-regression analysis of the literature since 1995 –comprising 51 primary studies– to identify the genuine representative effect established by this literature, after controlling for publication bias and sources of heterogeneity.

In this meta-regression analysis, we analyse a group of studies which evaluates the impact of the university-industry relationship on firms' performance. The heterogeneity between them is reflected in our literature review and meta-regression variables. Moreover, as there is no standard effect measurement in the literature, we transform the heterogeneous reported coefficients into partial correlation coefficients (PCCs). Using this effect-size standard measure and applying MRA, we can affirm that there is a genuine empirical effect beyond publication bias. This result is a contribution that complements previous literature reviews, which do not check for publication bias nor could estimate a genuine representative effect beyond publication bias.

Table 3.2 shows that positive publication bias exists, which may reflect the asymmetric weight of theory in this literature in reporting positive outcomes. In any case, estimation by meta-regression of the genuine effect identified a "small" positive effect after accommodating for publication bias. However, PCC is a standard measure yet not one of economic effect.

To provide a direct measure of impact on firms' performance, we analyse two subsamples of studies which analyse patent generation and innovative sales growth as examples of technical and economic outcomes. As both outcome measures are commonly used in the literature, the estimation of a genuine effect does not require any transformation, and the results can be interpreted from an impact perspective. Although the samples are small, the models diagnose satisfactorily and show that U-I cooperation has a significant medium-size effect on patent generation and small negative effect on innovative sales.

In sum, our MRA findings reject the negative effect of this cooperation on firms' performance, although the average effect is small. While the lack of evidence for substantial results might be disappointing for policymakers, this suggests that this may be typical of innovation policies. U-I collaboration is an important part of the innovative process, but it depends on the capacity that the firms have to absorb external knowledge. This conclusion contributes to the policy debate by identifying a representative U-I collaboration effect from the large and complex open-innovation literature.

U-I relationships contribute to companies' performance through technical outcomes rather than economic ones. We find that the U-I relationships need to orientate the analysis to the qualitative aspects which can address the individual differences for increasing outcome performance. This analysis could be especially important when collaborative research is implemented as part of a broader open-innovation policy to achieve projects which produce not only positive effects for firms, but also positive spillovers for all of society (Jaeger & Kopper, 2014).

Our results also have implications for research practice and the interpretation of findings in this literature. Multiple MRA contradicts main-stream thought. They reveal that finalisation-orientated relationships and innovative firms do not increase the impact on the estimated effect size. Now it is accepted that the "third mission" must be a fundamental part of a research organisations' future activities. Our findings suggest that non-innovative firms could benefit the most if the relationship is boosted with public funds.

In any case, the overall impact of a U-I relationship is underestimated by this evaluation literature because a knowledge spillover-effect is not accounted for. Firms might benefit from U-I relationships in a way that cannot be captured by traditional measurements. If so, the lack of substantial effect identified in this MRA may not fully capture the quality of the outcome (Zahringer et al., 2017). This possibility is consistent with the negative influence on the estimated effect size of using logit models to evaluate collaboration effects, because the logit model is only used to measure binary outcomes.

Furthermore, this work also faced certain limitations, such as the fact that the sample of quantitative parametric enterprise-level studies is smaller than that of qualitative studies or semi-parametric ones. First, studies carried out in the past tend not to report the coefficient of effect or standard error, and, to be strict regarding the meta-analysis, they have not been counted so as not to introduce any type of bias on the part of the researcher when it comes to quantifying them. Second, the extended use of a CIS-based survey limited the analysis of the effects of each type of scientific partner; we suffered a certain heterogeneity on our classifications because there is no unified perspective of what collaboration with universities or scientific partners is. Third, the standard "general-to-specific" approach (Stanley and Doucaliagos 2012, p. 90) could generate some false certainty about the "best model" selected (Steel, 2020).

To address these limitations, we propose that future works move towards mixed-analyses which can simultaneously address quantitative and qualitative aspects. These approaches have an opportunity to analyse the heterogeneity produced by different scientific partners beyond our classification. For example, it would be interesting to know how the RTOs differ among them or how the Technical Universities differ from other HEIs. Also, a quantitative approach would permit addressing specific time and subnational effects in those regions which have recently modified their scientific institutional frame (e.g., UK REF or Nordic FOKUS). In addition, we encourage future MRA studies of approaches to continue developing other types of model selection, such as Bayesian model averaging approaches (Steel, 2020) or other non-parametric approaches (Havranek and Sokolova, 2020).

Finally, taking these caveats into account, our results provide food for thought about the role played by the U-I interactions on a firm's performance. We offer a measurement of the effect size and an explanation about what variables increase the effect size estimate. Science-based innovation is an important factor for economic growth. Firms engaging in scientific partnerships innovate more. However, our results raise questions about how firms' internal dynamic or characteristics could improve the results of cooperation to maximise their performance and create more value. These results represent a challenge for academics, practitioners and decision-makers in their quest to design policies and strategies that would create more adequate conditions and environments for firms to perform better and be more competitive.

CHAPTER 4. EXTERNAL STAKEHOLDER ENGAGEMENT: COMPLEMENTARY AND SUBSTITUTIVE EFFECTS ON FIRMS' ECO-INNOVATION

Abstract

In this paper, we investigate whether firms' engagements in collaboration agreements with different types of external stakeholders produce complementary effects on the likelihood of eco-innovation. Although collaboration network and open eco-innovation theories affirm that the combination of external partners such as scientific partners, suppliers and customers produces complementary effects on the firm's likelihood of eco-innovation, several empirical studies found the existence of substitutive effects between them. To bridge this gap in the literature, we shape the nature of the interaction between different external partners, analysing an unbalanced panel sample of 10,918 innovative Spanish firms, covering the period 2008–2016. Our results show that firms that simultaneously collaborate with scientific partners, suppliers and customers generate partial complementary effects, which increase the firm's likelihood to eco-innovate the most, and that the combination of customer-collaboration with scientific partners, or supplier-collaboration, produces partial substitutive effects.

Keywords: collaboration agreements, complementarity, eco-innovation, external partners, stakeholder engagement

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4.1. Introduction

Environmental responsibility and sustainability are issues impossible to be ignored by the management of companies. External stakeholders are increasingly demanding firms to introduce environmental products and to reduce CO2 emissions as well as materials and energy waste (Jové-Llopis & Segarra-Blasco, 2018). Top managers can see these pressures as threats to their core business but also as an opportunity to obtain a competitive advantage exploiting these demands (Ghisetti et al., 2015; Goodman et al., 2017; Zubeltzu-Jaka et al., 2018). Collaboration agreements with external stakeholders let firms convert them into key partners in eco-innovation —to introduce new products, processes or services which generate value and significantly decrease environmental impacts (Fussler & James, 1996, p. 303; OECD, 2009)—.

Collaboration with external partners is regarded as a critical determinant for firms’ standard innovation (Belderbos et al., 2015; Jensen et al., 2007; Lundvall, 1992) and also for eco-innovation (Foray & Grübler, 1996; Hofman et al., 2020; Lee & Kim, 2011). For example, collaboration with scientific partners minimises the cost of internalising new technologies and materials (Cainelli et al., 2012; Cassiman & Veugelers, 2006; Horbach, 2016); collaboration with suppliers reduces CO2 emission or energy waste (Dangelico, 2016; Hofman et al., 2020; Vachon, 2007); and collaboration with customers explores sustainable market demands (Cohen & Vandenbergh, 2012; Hofman et al., 2020; Melander, 2019). Each type of external partner offers access to different key resources for firms' eco-innovation; several scholars have claimed that multiple collaboration agreements with external stakeholders can generate complementary effects and increase the firms' likelihood to eco-innovate (De Marchi, 2012; Mårtensson & Westerberg, 2016; Melander, 2017).

However, these theories have collided with a stream of empirical literature which claims that rather than be complementary, collaboration with multiple partners produces substitutive effects and diminishing returns (Fu, 2012; Laursen & Salter, 2006; Leiponen & Helfat, 2010). These scholars argue that an excessive number of collaborators introduces an amount of information and complexity impossible to be handled by the firm’s managers; this situation produces a direct negative effect on firms' eco-innovation performance (Christensen, 2011; Ghisetti et al., 2015; Ketata et al., 2015). Thus, since the existence of the diminishing results has been checked empirically, the analysis of multi-partner collaboration effects has advanced to consider other attributes which can moderate the complementary effects on firms' likelihood to eco-innovate. For example, the level of trust (e.g., González-Moreno et al., 2019) or the existence of interactive effects in the combination of different types of external collaborations (e.g., Bönte & Dienes, 2013; Hofman et al., 2020; Kobarg et al., 2020; Marzucchi & Montresor, 2017).

Eco-innovation studies that consider interactive effects among different external partners on firms' eco-innovation outcomes have been few and far between. Moreover, their results are contradictory; some studies found "suppliers and customers" as complementary stakeholders (Du et al., 2018; Melander, 2020; Rauter, Globocnik, Perl-Vorbach, & Baumgartner, 2019), while others regarded them as substitutive ones (Hofman et al., 2020; Wei et al., 2020). This lack of consensus can also be addressed in other combinations such as "suppliers and scientific partners" (Bönte & Dienes, 2013; Marzucchi & Montresor, 2017; Mothe et al., 2018) or "customer and scientific partners" (Mothe et al., 2018; Rauter et al., 2019). Therefore, as revealed in several literature reviews, the impact of combining multiple external stakeholders on firms' eco-innovation needs to be analysed in depth to connect theory with managerial implications for collaboration networks and open eco-innovation strategies (Dangelico, 2016, p. 573; Del Rio et al., 2016, p. 2169; Ehls et al., 2020, p. 420; Johnsen, 2009, p. 197).

Consequently, the aim of this paper is to analyse the existence of interactive effects between collaboration agreements with different types of external stakeholders. Specifically, we focus on those which the literature point to as having a bigger effect on firms' likelihood to eco-innovate: scientific partners, suppliers and customers. Based on these previous studies (e.g., Bönte & Dienes, 2013; Du et al., 2018; Hofman et al., 2020; Kobarg et al., 2020; Marzucchi & Montresor, 2017; Melander & Pazirandeh, 2019), we suggest that the contradictory effects reported in the literature are caused by complex interactive effects resulting from the type of external partners combined.

To answer this research question, we conducted our analysis of an unbalanced panel sample of 10,918 Spanish firms during the period 2008-2016. The panel is constructed with data from the Spanish version of the Community Innovation Survey (Panel de Innovación Tecnológica, PITEC). Using a marginal effect analysis, we estimate the effect of every possible combination of external partner collaboration on a firms' likelihood to eco-innovate. This research represents the first time that this technique has been applied to analyse the interactive effects between external partners on a firm's likelihood to eco-innovate.

The results show that simultaneous collaboration with "scientific partners, suppliers, and customers" is what increases the firms' likelihood to eco-innovate the most. The combination of "scientific partners and suppliers" shows partial complementary effects, while the combination of "scientific partners and customers" and "suppliers and customers" show partial substitutive effects. Finally, our result confirms the literature background that engaging with scientific partners, suppliers or customer independently from one another increases firms' likelihood to eco-innovate more. Mainly, this study provides practitioners with a correct understanding of the benefits that they can expect to obtain from multi-partner external collaboration.

This paper is organised as follows. In the next section, we review pertinent literature on the role of eco-innovation of different external stakeholders. In Section 4.3, we present the sample and the methodology used to analyse the data. In Section 4.4, we present the results from the empirical analysis. In section 4.5, we discuss the result. The main conclusions and the future lines are presented in the final section.

4.2. Literature background

4.2.1. Collaboration agreements with external stakeholders

Practitioners and innovation management scholars regard collaboration agreements with firms' external stakeholders as a critical determinant for firms' innovation (van Beers & Zand, 2014). Making them key partners lets firms access resources and infrastructures which have a significant impact on firms' innovative performance (Belderbos et al., 2004; Belderbos et al., 2015). One of the most widely used mechanisms to formalise cooperative relationships with external stakeholder is “collaboration agreements” (Martínez-Noya & Narula, 2018). Collaboration agreements can be defined as formal partnership agreements among different organisations to pursue an innovative assignment (Arranz & Fdez. de Arroyabe, 2008). This mechanism reduces transactional costs and generates mutual benefits (Hagedoorn et al., 2000). Although they can be formalised with all types of stakeholders, firms prefer to establish collaborative agreements with non-competitors such as scientific partners, suppliers and customers because they are perceived as partners with fewer options to develop an opportunistic behaviour (Martínez-Noya & Narula, 2018; Nieto & Santamaría, 2007; Rauter et al., 2019).

Collaboration agreements with scientific partners –universities, research institutes and other research organisations– let firms access advanced R&D activities, infrastructures and human capital, reducing the cost of internalising them (Cassiman & Veugelers, 2002; Perkmann & Walsh, 2007). During the last decade, these scientific actors have increased their engagement in collaborative projects with private organisations to transform their basic knowledge into applied knowledge, creating value for society through market-oriented projects (Barge-Gil & Modrego, 2011). As recent literature reviews pointed out, (Mascarenhas, Ferreira, & Marques, 2018; Vivas & Barge-Gil, 2015), collaboration with scientific partners is a key determinant of firms’ innovation.

Eco-innovation scholars share this point of view (Foster & Green, 2000; Steward & Conway, 1998). Moreover, they claim that as scientific partners have been engaging in collaboration agreements with firms, they have done it focusing on sustainable environmental challenges. Specially, their collaboration has been orientated to develop new technologies capable of reducing CO2 emissions and using new, less environmentally damaging materials (Demirel & Kesidou, 2019; Fabrizi et al., 2018; Ghisetti & Pontoni, 2015). Several studies have shown the importance of firms’ collaborating with scientific partners (Triguero et al., 2013) and the positive impact that this collaboration has on firms’ eco-innovation (Cainelli et al., 2012; De Marchi & Grandinetti, 2013; Horbach, 2016).

For example, Cainelli et al. (2012) analysed a sample of 555 Italian manufacturing firms and showed how a university positively affects the introduction of eco-innovations more than any other collaboration agreement. De Marchi & Grandinetti (2013) also showed in a sample of 1,831 Italian firms how collaboration with universities, research institutes and consultants is an essential driver of firms' eco-innovation. Additionally, Horbach (2016) showed how important it is for firms to collaborate with public research institutes to introduce eco-innovation related to new materials in a sample of western European firms, and to introduce eco-innovations related to CO2 emissions in a sample of eastern European firms. Based on this empirical and theoretical literature, we expect to find that scientific partner-collaboration positively affects firms' likelihood of eco-innovating. This first hypothesis can be summarized as follows:

H1: Firms which collaborate with scientific partners are more likely to introduce eco-innovation than those that do not.

Upstream collaboration agreements with suppliers contribute to firms' innovation, sharpening its focus on core competencies, bettering design processes, and securing vital inputs (Belderbos et al., 2015). Supplier-collaboration can also create additional opportunities for firms to add value, for example, steering their innovation efforts in the firms' interest (Ragatz et al., 1997). The effective integration of suppliers into firms' innovations can help them achieve a competitive advantage in terms of cost, technologies and time (Chung & Kim, 2003; Nieto & Santamaría, 2007; Un & Asakawa, 2015).

Due to its orientation towards introducing efficient technologies, supplier-collaboration is significantly related to reducing CO2 emissions, energy and materials waste (Foster & Green, 2000; Green et al., 1994; Johnsen, 2009). Thus, eco-innovation literature has regarded this type of collaboration as an essential source of firms' eco-innovation (Dangelico, 2016; Johnsen, 2009). This type of collaboration could be accomplished by pursuing a productivity goal, but it also positively impacts the environment (Sarkis et al., 2011; Vachon, 2007). Recently, this type of eco-innovation also pursued satisfying market demands related to environmental standards of quality such as ISO 14001 or eco-labelling

(Melander, 2018; Papagiannakis et al., 2019). Scholars have widely demonstrated how collaboration with suppliers is a critical factor of eco-innovation (Bos-Brouwers, 2010; Lee & Kim, 2011; Pujari et al., 2003).

For example, Pujari et al. (2003) shows in a sample of 151 UK manufacturing firms that a higher degree of supplier involvement positively influences eco-innovation performance. Bos-Brouwers (2010) found similar results in a qualitative study of Austrian firms. They found that supplier collaboration is focused on introducing new materials or technologies which increases the firms' likelihood of eco-innovating. Lee & Kim (2011) studied the Korean semiconductor industry and showed how collaboration with suppliers is a strategic relationship to develop successful eco-innovation, bringing environmental and commercial success together. Based on this empirical and theoretical literature, we suggest that collaboration with suppliers positively affects a firms' likelihood of eco-innovating. This second hypothesis can be summarized as follows:

H2: Firms that collaborate with suppliers are more likely to eco-innovate than those that do not.

Last but not least, downstream collaboration agreements with customers are also vital for firms' standard innovation (Von Hippel, 1978, 2005). Customer collaborations have been used to reduce the risks associated with the introduction of new products in a heterogeneous market where the cost of internalising the customer demands is high (Sánchez-González et al., 2009; Von Hippel, 2005). Customer collaboration is also used to improve firms' products and services, thereby introducing incremental innovations (Belderbos et al., 2004, 2015). Although innovation literature has been focused on the role played by customer collaboration in the commercialisation of product-innovations (He & Wang, 2016; Stockstrom et al., 2016), several studies have also shown the relevance of this relationship to firms' process-innovation (Chen & Tsou, 2012).

From an eco-innovation perspective, customer collaboration is the determinant partner for firms to introduce eco-innovations. Through their purchasing decision, customers can reward firms which satisfy their environmental consciousness and punish firms which do not (Campbell, 2007). Making these decisions is comfortable, talking about product innovation for which environmental specifications are easily verifiable (e.g., related to materials or packaging). Nevertheless, as Kobarg et al. (2020) point out, making this decision when the ecological innovation is related to processes implies trusting what is defined as a “credence feature” (Rex & Baumann, 2007). The environmental impact developed previously in the back-door process is hard for the customer to recognise (De Marchi & Grandinetti, 2013). Despite the existence of this psychological disincentive (Dulleck et al., 2011), several studies have shown that this problem is becoming less and less relevant thanks to more information that customers have because of successful environmental labelling policies. These have increased the ecological perspective of society (Baksi et al., 2017; Cohen & Vandenbergh, 2012) and have a positive impact on firms’ likelihood to eco-innovate (Kammerer, 2009; Liao & Tsai, 2019; Melander, 2018).

For example, Kammerer (2009) showed how customers play a crucial role in the introduction of eco-innovations in a sample of 92 German manufacturers. They found that firms which attributed a considerable potential for customer benefit to an environmental issue were significantly more likely to implement eco-innovations orientated towards solving this issue than others. Melander (2018) qualitatively studied ten different eco-innovations with data from five large industrial firms. Her work explained how customers contribute positively in the early phase by generating ideas and providing knowledge about the market, customers’ requests, and environmental requirements. In the end phase, customers contribute positively by participating in testing the product as pilot users. Finally, Liao & Tsai (2019) checked, in a sample of 1,717 Taiwanese service firms, how customer demand influences firms to adopt eco-innovation and how their achievement is directly related to firms’ performance. Based on this empirical and theoretical literature, we expect to find that customer collaboration positively affects firms’ likelihood to eco-innovate. This third hypothesis can be formulated as follows:

H3: Firms which collaborate with customers are more likely to introduce eco-innovations than those which do not.

4.2.2. Complementarity among different external stakeholder

The competition in the market has forced organisations to formalize collaboration agreements with more than one external stakeholder to increase firms' opportunities to explore and exploit their resources (Belderbos et al., 2015; West & Bogers, 2014). Innovation management theory widely supports the contention that simultaneous collaboration with different external stakeholders can generate complementary effects on firms' innovation (Faems et al., 2005; Jensen et al., 2007; Tether, 2002). However, empirical studies which have analysed multi-partner collaboration have found that beyond an optimal level, firms that rely on an increasing number of external partners suffer from decreasing returns in terms of innovation performance (Laursen and Salter, 2006). These studies claim that as the number of external collaborations increases, the complexity and the challenge of dealing with them increases as well (Fu, 2012; Stuermer et al., 2009).

Thus, firms must confront this trade-off between the benefits and costs of collaboration by aligning search breadth and depth with other factors, allowing them to overcome the impediments of relying on different external stakeholders (Powell et al., 1996; Tödtling et al., 2009). That is why many scholars have suggested that complementary effects depend not on their number, but rather on their type (Belderbos et al., 2015; González-Pernía et al., 2015; Haus-Reve, et al., 2019; Jensen et al., 2007). From this perspective, collaborating only with suppliers could be less effective regarding firm innovation than combining collaboration with supplier and scientific partner. The few studies which have analysed the existence of these interactive effects on standard innovation have shown contradictory results. González-Pernía et al. (2015) found positive results in firms' simultaneous collaboration with supply-chain partners and scientific ones in a sample of 4,969 innovative Spanish firms covering the period 2003-2011, while Haus-Reve et al. (2019) found the opposite results in a sample of 4,534 Norwegian firms covering the period 2006–2010.

From an eco-innovation perspective, the existence of complementary effects between external partners has been more accepted by theory and practice than in standard innovation (Dangelico, 2016; Del Río et al., 2016; Foster & Green, 2000). For example, De Marchi (2012) and Triguero et al. (2013) demonstrated how eco-innovations benefit more from collaboration agreements than standard innovation, although other studies have also found the existence of dismissing results as the number of partners grows (Bönte & Dienes, 2013; Christensen, 2011; Ghisetti et al., 2015; Ketata et al., 2015). Due to the importance of collaboration for firms and society, scholars reaffirm the undeniable benefits of broader collaboration agreements with external stakeholders. Theoretically, this point has been addressed from two important streams of literature: the collaborative networks perspective and the ecosystem approach.

The collaborative network perspective relies on social capital theory (Cainelli et al., 2007; Cainelli et al., 2012), interfirm agreements and knowledge spillovers in industrial areas (Geffen & Rothenberg, 2000; Steward & Conway, 1998). From this perspective, the network can partially substitutive economies of scale in an environment characterised by small and medium firms (Mazzanti & Zoboli, 2009) and generate positive impacts on the firms and aggregated levels (Fritsch & Schwirten, 1999; Fritsch, 2001). Collaboration agreements in this network can save raw materials, improve waste disposal, limit polluting emissions or reduce energy consumption, packaging and transportation (Cantono & Silverberg, 2009; Manzini & Vezzoli, 2003). Moreover, it has been proven that being part of the network encourages firms to change their behaviours and values to become more environmentally-friendly (Marcon et al., 2017).

Empirical studies which have studied collaborative networks and firms' eco-innovation have found a positive relationship between them (Inigo et al., 2020; Ma et al., 2017; Melander & Pazirandeh, 2019; Melane-Lavado & Álvarez-Herranz, 2020; Pellegrini et al., 2019). For instance, Ma et al. (2017) who analysed Chinese joint-filing patents over the period 2006–2015, found that external collaborations have moved toward a higher level of multidisciplinary and larger technological distance, positively influencing the introduction of eco-innovations related to waste-of-energy reductions. Melander & Pazirandeh (2019) interviewed thirty top managers from the high-technological sector and found that firms which collaborate with inter-industry and intra-industry partners eco-innovate more. Inigo et al. (2020) analysed a sample of 170 firms in Spain's Basque Country region –which has a highly collaborative regional innovation system– and found that collaboration proactiveness is positively related to firms' eco-innovation.

The ecosystem approach focuses on the complex social-ecological nature of the sustainability challenge (Dietz et al., 2003, p. 1908) and tries to analyse the nonlinear interactions of the economic, social and environmental spheres, as well as the necessity of societal cross-sector collaboration in support of sustainability and conservation efforts (Costanza et al., 2007). In this approach, the firms and other organisations are part of the ecosystem and cannot be separated from it (Slocombe, 1993). Thus, all the ecosystem members have a common goal of sustainability development and are coordinated by the institutional agents (Bengtsson & Kock, 2000; Folke, 2006; Dahl, 2014).

Empirically, this ecosystem approach has found that multiple types of well-established relationships between different partners are needed in order to achieve firms' higher level of eco-innovation (Behnam et al., 2018; Planko et al., 2019; Wei et al., 2020). For example, Planko et al. (2019) have shown the importance of trust and shared goals in the Dutch smart grid industry and Wei et al., (2020) found similar results studying three different cases from the platform service industry. And, Behnam et al. (2018) found that networking, competence mapping and relational capabilities with other agents strongly depend on the eco-innovation outcome characteristics.

Both theoretical frameworks have been combined in open eco-innovation studies which have analysed whether the combination of multiple collaborative agreements with external partners generates a positive effect or not (e.g., Cuerva et al., 2014; Ghisetti et al., 2015; Horbach et al., 2013; Horbach et al., 2012). For example, Cuerva et al. (2014) found that supply-chain partners positively affect eco-innovation in a sample of 205 Spanish SMEs from Low-Tech sectors, as did Horbach et al. (2012) in an analysis of 1,294 German firms.

However, few studies have analysed the existence of complementary or substitutive effects between different types of external stakeholders, and those which have, show contradictory results (Hofman et al., 2020; Kobarg et al., 2020; Rauter et al., 2019; Wei et al., 2020). Some of them found suppliers and customers as complementary partners (Melander, 2019; Rauter et al., 2019), while others regarded them as substitutive ones (Hofman et al., 2020; Wei et al., 2020). This contradiction can also be addressed in other combinations such as suppliers and scientific partners (Kobarg et al., 2020; Mothe et al., 2018). Recently, Kobarg et al. (2020) have quantitatively analysed the combination of scientific partners, suppliers and customers. These authors studied 546 German firms, and found mixed effects: a positive effect on the combination of scientific partners, suppliers and customer, but neutral effects between scientific partners and customers, and adverse ones between suppliers and customers.

Theoretically, based on the benefits that extended collaborative network and interactive environments have on firms' eco-innovations for all of society, we expect that the combination of different types of partners has a positive effect on the firms' likelihood to eco-innovate to higher levels than those which only cooperate with one type of partner. This fourth hypothesis can be formulated as follows (Melander & Pazirandeh, 2019; Pellegrini et al., 2019; Planko et al., 2019; Wei et al., 2020). However, due to other empirical literature, which has pointed out the existence of substitutive effects, we do not disregard the adverse effects on specific external partner combinations (Hofman et al., 2020; Kobarg et al., 2020; Wei et al., 2020).

H4: Firms which collaborate with scientific partners, suppliers, and customers are more likely to eco-innovate than those with only one partner.

4.3. Methodology

4.3.1. Dataset

We tested the hypotheses presented above using data from the Spanish Technological Innovation Panel (PITEC). This panel survey is based on the Community Innovation Survey (CIS), and is one of the most used datasets in innovation studies (e.g., Cainelli et al., 2015; De Marchi, 2012; Del Río et al., 2016; Jové-Llopis & Segarra-Blasco, 2018, 2020; Marzucchi & Montresor, 2017). Since 2008, PITEC includes variables related to environmental innovation objectives in each survey series following the Oslo Manual. These variables have been used in both cross-sectional (Arranz et al., 2019; De Marchi, 2012) and panel analysis (Jové-Llopis & Segarra-Blasco, 2020; Marzucchi & Montresor, 2017). Nowadays, the main advantage of the PITEC database is its time dimension which allows us to deal with unobserved heterogeneity and simultaneity problems.

In our analysis, we use an unbalanced panel of innovative firms from the time-period 2008-2016. As in previous literature (González-Pernía et al., 2015; Haus-Reve et al., 2019), we excluded earlier observations from firms that have suffered sudden employment changes resulting from a merger or acquisition process, high labour turnover or layoffs. The resulting sample is composed of 10,918 firms, during an average period of 7.1 years, yielding a total sample of 67,982 observations. In 2016, almost a third of the firms eco-innovated, indicating an increasing trend among innovative Spanish firms.

4.3.2. Variables

As the dependent variable, we analyse firms' engagement in eco-innovation, based on their ex-post self-assessment. For that, we utilise a PITEC question of asks (on a four-point scale) to what degree the firm has introduced any innovation pursuing an environmental objective. We coded this question as a binary variable (positive values if the firm responds "strong or medium", negative otherwise). This dependent variable offers the best approach to determining a firms' likelihood of eco-innovating as previous studies have shown (e.g., Cainelli et al., 2015; De Marchi, 2012; Del Río et al., 2016; Horbach, 2008; Marzucchi & Montresor, 2017). In this sample, 53.68% of firms have declared to have introduced eco-innovations during the period analysed at least once.

As independent variables, we use questions about the existence of collaboration agreements with firms' external stakeholders. Although the specification of the type of external partners is a common practice in innovation studies (e.g., Faems et al., 2005; Fitjar & Rodríguez-Pose, 2013; Haus-Reve et al., 2019), eco-innovation studies tend to treat firms' external collaboration as a single binary variable (e.g., De Marchi, 2012; Marzucchi & Montresor, 2017; Triguero et al., 2013), but this codification could bias the result, mixing and hiding interactive effects. That is why notable exceptions in this field have tried to analyse what the specific effect produced by different partner combinations is (e.g., Bönte & Dienes, 2013; Cuerva et al., 2014; Del Río et al., 2016; Kiefer et al., 2019; Kobarg et al., 2020; Sáez-Martínez et al., 2016). Following their approach, we use the binary questions of PITEC about collaboration agreements to construct our independent variables. First, we coded collaboration with scientific partners (STI) as a positive value if the firm responded affirmatively to collaboration with universities or research institutes (Cainelli et al., 2012; Horbach, 2016). Second, we coded upstream collaboration with suppliers positively when the firm responded affirmatively to have engaged collaboration agreements with this partner (Dangelico, 2016; Melander, 2017). Third, we coded downstream collaboration with customers positively if the firm responded affirmatively (Kobarg et al., 2020; Melander, 2020).

As control variables, we used several factors at firm, sectoral and regional level which may influence firms' eco-innovation and have been taken into account in previous studies (Del Río et al., 2016): Collaboration with competitors, subsidies, firms' R&D internal expenditure, share of exports in turnover, size, age, sector and region. The correlation estimation between them tends to be low, suggesting that severe multicollinearity is not a problem (VIF = 1.36) –See correlation matrix in Appendix Table 4.A–.

At the firm level, we controlled for collaboration with competitors. Although empirical studies have found that coopetition has a positive effect on a firm's likelihood to eco-innovate (Bouncken et al., 2015; Ritala & Hurmelinna-Laukkanen, 2013), firms prefer to establish collaborative agreements with non-competitive partners because the latter are perceived as partners with fewer options to develop an opportunistic behaviour (Martínez-Noya & Narula, 2018; Nieto & Santamaría, 2007; Rauter et al., 2019). Based on this literature, we expect collaboration with competitors to have a neutral or small positive effect on firms' likelihood to eco-innovate. We employ the dummy variable, subsidies, referring to the firms' reception of funds to innovate from a public institution, although data constraints do not enable us to relate this policy to eco-innovation (Jové-Llopis & Segarra-Blasco, 2018; Triguero et al., 2013; Veugelers, 2012). Because of that, we expect that this variable and the firms' likelihood to innovate remain neutral.

Table 4.1. Summary statistics of the variables used in the estimations

Variables	Description	Mean (σ)
Eco-innovation	Dummy variable taking the value 1 if firm introduced any innovation with a medium or strong environmental-objective in the preceding three years; 0 if not	0.323 (0.468)
Scientific partners (STI)	Dummy variable taking the value 1 if firm collaborated with universities, research institutes or consultancy firms in the preceding three years; 0 if not	0.197 (0.398)
Suppliers	Dummy variable taking the value 1 if firm collaborated with suppliers in the preceding 3 years; 0 if not	0.123 (0.328)
Customers	Dummy variable taking the value 1 if firm collaborated with customers in the preceding 3 years; 0 if not	0.100 (0.300)
Competitors	Dummy variable taking the value 1 if firm collaborated with competitors in the preceding 3 years; 0 if not	0.067 (0.251)
R&D expenditure (log)	Log of total expenditure on research and development activities in the preceding three years	6.716 (6.382)
Firm age (log)	Log of number of years since firm foundation up to year of the survey	2.752 (1.224)
Firm size (log)	Log of number of full-time employees in firm in the year of the survey	4.123 (1.748)
Share of Exports (%)	Share of firm's sales in non-domestic market in the year of the survey	20.278 (30.21)
Subsidies	Dummy variables taking the value 1 if firm received funds from a public institution to innovate in the preceding three years; 0 if not	0.150 (0.358)
Manufacturing High Technology	Dummy variable taking the value 1 if firm sector is: Pharmaceutical; Computing (Hardware), Optics or Electronics and Aeronautics; 0 if not	0.043 (0.202)
Manufacturing Medium-High Technology	Dummy variable taking the value 1 if firm sector is: Chemistry, Metallurgy; Electrical equipment and supplies; Other machinery; Motor vehicles; Other Transportation or Other Manufacturing Assets; 0 if not	0.235 (0.424)
Service High Technology	Dummy variable taking the value 1 if firm sector is: Computing (Software) or R&D Services; 0 if not	0.047 (0.202)
Innovative Region	Dummy variable taking the value 1 if firm is settled in Madrid, Basque Country or Catalonia; 0 if not	0.249 (0.432)

Source: Own Elaboration

In addition, we controlled for firm's internal R&D expenditure and share of exports in turnover. Although previous literature has shown contradictory conclusions about whether R&D investment increases firms' likelihood to eco-innovate (Cainelli et al., 2015, 2012; Marzucchi & Montresor, 2017), we expect that higher levels of internal R&D expenditure will have a positive effect. Otherwise, previous studies have not found a strong relationship between firm's exports and eco-innovation. That is why we expect to find a neutral effect (Cainelli et al., 2012; Marzucchi & Montresor, 2017). Finally, we use the firm's size (total number of employees) and age (number of years since founding) to control firms' internal characteristics such as experience, management capabilities and ability to obtain resources. We accept that older and big firms may benefit from building on previous routines and capabilities to increase their likelihood to eco-innovate (Del Río et al., 2016).

At the sectoral level, based on previous literature (Del Río et al., 2016; Jové-Llopis & Segarra-Blasco, 2018; Segarra-Oña, Peiró-Signes, & Mondéjar-Jiménez, 2016), we point out the existence of differences between service and manufacturing firms and their technological levels. To control these differences, we classify firms as belonging to a high or medium-high technology level in the manufacturing or services sector. We assign a group of three dummy variables based on NACE Rev.2 classification (Eurostat, 2018) – See Table 4.1 for further description–: High technology manufacturing, Medium-high technology manufacturing, and High technology services. We accept that medium-high technology manufacturers are more likely to eco-innovate than any other firm (Segarra-Oña et al., 2016).

Finally, regional characteristics were coded as a dummy variable: Innovative Region - taking the positive value if the firm is established in the Spanish regions of Madrid, Basque Country or Catalonia, negative otherwise. These regions are considered the most innovative Spain regions (Barajas & Huergo, 2010; Herrera & Nieto, 2008; Inigo et al., 2020). According to previous literature, we expect that being settled in these regions increases the firm's likelihood of eco-innovating due to being part of an ecosystem with broader collaborative networks (Inigo et al., 2020).

4.3.3. Methods

To test our hypotheses, we established the following panel regression model.

Equation 4.1 $$logit(P(EI_{i,t})) = \beta_0 + \beta_1 EI_{i,t-1} + \beta_2 (Collab_{i,t}) + \beta_3 Z_{i,t} + \varepsilon_{i,t} + \alpha_i$$

$P(EI_{i,t})$ is the likelihood of eco-innovation for firm i at time t. We decided to deal with unobserved heterogeneity, controlling for firms' eco-innovation in the last period ($EI_{i,t-1}$). The vector $Collab_{i,t} = (STI_{i,t}, Suppliers_{i,t}, Customers_{i,t})$ captured firm i collaboration at time t. The $Z_{i,t}$ vector refers to a firm's control variables, including industrial and regional ones. This econometric approach is consistent with previous studies of firms' innovation modes (Faems et al., 2005; Fitjar & Rodríguez-Pose, 2013; González-Pernía et al., 2015; Haus-Reve et al., 2019; Jensen et al., 2007) and eco-innovation studies (Frondel et al., 2007; Marzucchi & Montresor, 2017; Veugelers, 2012; Wagner, 2007, 2008). As in previous literature (De Marchi, 2012; Haus-Reve et al., 2019; Marzucchi & Montresor, 2017), because of the unobservable influences of endogeneity, we validate our results using a fixed-effects model (also known as a 'within panel data' model).

4.4. Results

Table 4.2 shows the estimates for eco-innovation following a general-to-specific model approach. In column 1, firms' likelihood to eco-innovate is a function of itself in the previous period as well as control variables. In the next columns several combinations of external partners are shown until the final model in which all possible combinations are analysed. As expected, innovating in the preceding period makes firms significantly more likely to eco-innovate in the analysed period. In column 2, the estimates confirm that collaborating with scientific partners, suppliers or customers independently of one another increases a firms' likelihood to eco-innovate more than firms which do not collaborate with any partner. This result confirms our hypothesis H1-H3, the existence of a positive effect derived from what eco-innovation literature defines as firm's collaboration or cooperation (De Marchi, 2012; Del Río et al., 2016; Melander, 2017).

In all the model specifications the estimated coefficients for the control variables are in line with expectations. Collaboration with competitors is only relevant if firms do not collaborate with any other partner. If collaboration with non-competitive partners is taken into account, horizontal collaboration does not have a significant effect on firms' eco-innovation. Innovation subsidies have a negative small-size effect on firms' likelihood of eco-innovation. R&D expenditure has a positive effect on eco-innovation, as do firms' exports, but this last one has only a small effect size. A firm's age and size produce different results, the former having a positive impact on the firms' likelihood to innovate, and the latter not showing a significant effect. Regarding sectorial variables, medium-high technology manufactures are more likely to introduce eco-innovations than those of any other sector. Moreover, being a high-tech services firm has a negative effect on the likelihood to eco-innovate. Finally, at regional level, the results show that firms from more innovative Spanish regions do not eco-innovate more than firms from other regions.

4.4.1. Estimating complementarity

To answer the main question of this research –whether or not there exist complementary effects between different types of external partners on the firms' likelihood to eco-innovate– we have to study the interactions between them. As Ai & Norton (2003) state, interactions cannot be evaluated simply by looking at the sign, magnitude, or statistical significance of the coefficient on the interaction term when the model, as here, is non-linear. Instead, the interaction effect requires computing the cross-derivative or cross-difference effects (Cornelißen & Sonderhof, 2009). Thus, we have to regard with caution the estimated effect of the panel model and following that, analyse the different marginal effects of each type of collaboration to provide the correct estimated interaction (Buis, 2010; Haus-Reve et al., 2019).

Table 4.2. Random-effect model, eco-innovation. Unbalanced panel

Variables	(1) Coef. (S.E.)	(2) Coef. (S.E.)	(3) Coef. (S.E.)	(4) Coef. (S.E.)	(5) Coef. (S.E.)	(6) Coef. (S.E.)	(7) Coef. (S.E.)
Eco-innovation$_{t-1}$	2.998*** (0.031)	2.945*** (0.032)	2.945***(0.032)	2.945*** (0.032)	2.971*** (0.314)	2.945*** (0.032)	2.950*** (0.032)
Scientific partner (STI)		0.440*** (0.040)	0.519*** (0.043)	0.580*** (0.042)		0.548*** (0.046)	0.578*** (0.047)
Suppliers		0.230***(0.044)	0.365***(0.063)		0.360*** (0.050)	0.196*** (0.067)	0.265*** (0.071)
Customers		0.282*** (0.050)		0.810*** (0.084)	0.450*** (0.061)	0.692*** (0.094)	0.854*** (0.109)
STI*Suppliers			-0.125 (0.083)			-0.023 (0.090)	-0.171* (0.103)
STI*Customers				-0.670*** (0.099)		-0.664*** (0.104)	-0.910*** (0.133)
Suppliers*Customers					-0.100 (0.090)	0.115 (0.097)	-0.323* (0.177)
STI*Suppliers*Customers							0.621*** (0.210)
Competitors	0.303*** (0.050)	-0.030 (0.055)	0.024 (0.054)	0.013 (0.054)	0.084 (0.054)	-0.015 (0.055)	-0.019 (0.055)
Subsidies	0.061 (0.038)	-0.087** (0.040)	-0.071* (0.040)	-0.090** (0.040)	-0.007 (0.039)	-0.085** (0.040)	-0.087** (0.040)
R&D expenditures (log)	0.189*** (0.003)	0.183*** (0.003)	0.182*** (0.003)	0.182*** (0.003)	0.185*** (0.003)	0.181*** (0.003)	0.181*** (0.003)
Share of exports (%)	0.002*** (0.001)	0.002*** (0.001)	0.002*** (0.001)	0.002*** (0.001)	0.002*** (0.001)	0.002*** (0.001)	0.002*** (0.001)
Firm size (log)	-0.004 (0.010)	-0.012 (0.010)	-0.012 (0.010)	-0.004 (0.010)	-0.013 (0.010)	-0.009 (0.010)	-0.009 (0.010)
Firm age (log)	0.142*** (0.026)	0.154*** (0.027)	0.148*** (0.027)	0.158*** (0.027)	0.148*** (0.027)	0.155*** (0.027)	0.155*** (0.027)
Manuf. (high technology)	-0.024 (0.068)	-0.178 (0.070)	-0.132 (0.071)	-0.019 (0.070)	-0.020 (0.069)	-0.017 (0.067)	-0.016 (0.070)
Manuf. (med-high tech.)	0.221*** (0.036)	0.243*** (0.037)	0.248*** (0.037)	0.244*** (0.037)	0.226*** (0.036)	0.245*** (0.037)	0.246*** (0.037)
Service (high technology)	-0.294*** (0.069)	-0.342*** (0.071)	-0.316*** (0.071)	-0.333*** (0.071)	-0.337*** (0.070)	-0.329*** (0.071)	-0.331*** (0.070)
Innovative Region	-0.178*** (0.035)	-0.171*** (0.035)	-0.164*** (0.035)	-0.175*** (0.035)	-0.181*** (0.035)	-0.173*** (0.036)	-0.173*** (0.036)
Constant	-4.061*** (0.088)	-4.010*** (0.091)	-4.087*** (0.091)	-4.150*** (0.091)	-4.056*** (0.089)	-4.121*** (0.091)	-4.130*** (0.091)
Year	YES	YES	YES	YES	YES	YES	YES
Log Likelihood	-22264.922	-22102.469	-22117.488	-22093.201	-22164.017	-22080.19	-22075.82
Wald chi^2	17881.15 (18)	17423.94 (21)	17453.23 (21)	17449.70 (21)	17651.70 (21)	17426.82 (24)	17409.52 (25)
Observations	67,982	67,982	67,982	67,982	67,982	67,982	67,982
Firms	10,918	10,918	10,918	10,918	10,918	10,918	10,918

*Note: Asterisks indicate significance levels of *1, **5 and ***10%. Source: Own Elaboration*

Table 4.2 shows the estimated coefficients of the interaction terms among different types of collaboration (Col. 3-6) show that the combination of two partners can have a negative (“scientific partners and customers”) or non-significant effect (“scientific partners and suppliers” and “suppliers and customers”) on firms’ likelihood to eco-innovative in comparison to a no-collaboration situation. In the final model (Col. 7), the collaboration with all types of partners (“STI, suppliers and customers”) reflect a positive effect, while the combinations of two partners keep their negative sense but increase their statistical significance. The estimated coefficient of the collaboration with the three partner shows the second biggest impact on the likelihood of eco-innovate after customer collaboration. However, as we discuss before, the existence of an interactive between different types of external partners in this non-linear model requires an analysis of the marginal differences (Ai & Norton, 2003; Mitchell, 2012).

The marginal difference analysis, also known as marginal analysis, computes the difference between the expected probability of eco-innovation of each partner combination rather than the derivative of the effect expected probability with respect to no-collaboration. The reason for computing the marginal effect this way is that our independent variables are categorical ones, so the discrete difference corresponds more closely with what would actually be observed in reality. Table 4.3 shows the marginal effects on the probability of firms’ eco-innovation in different types of collaboration at average levels of the control variable.

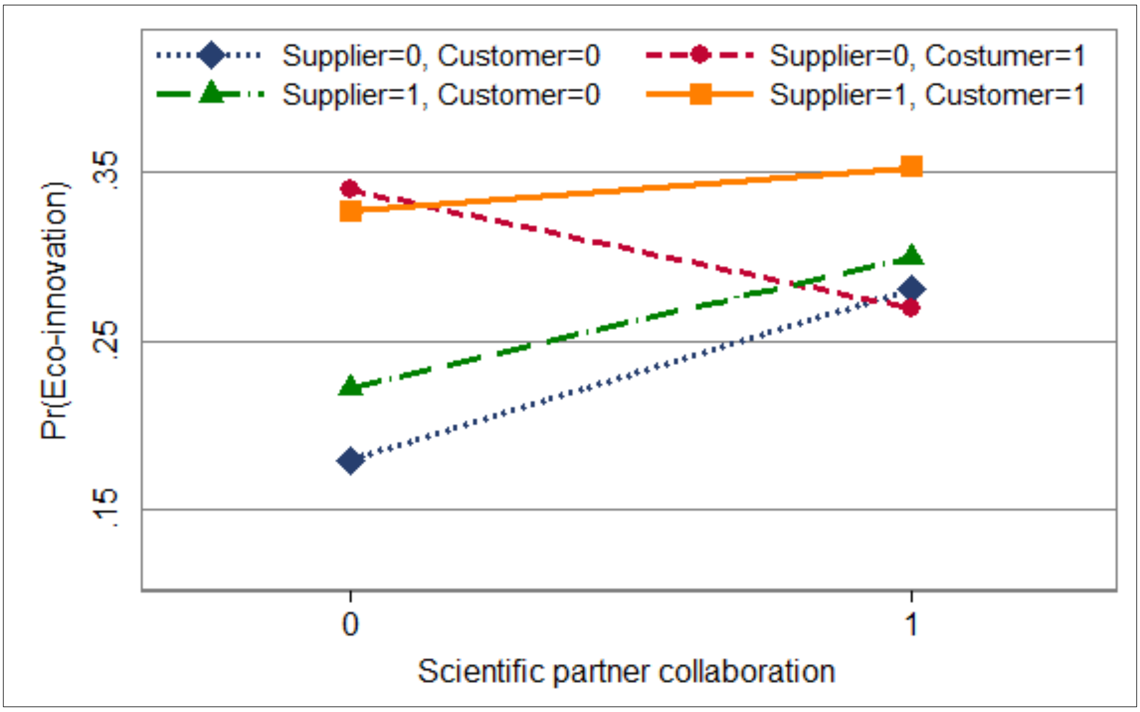
Table 4.3. Marginal effects of different types of collaboration on eco-innovation

	Scientific partners=0	Scientific partners=1
Suppliers=0, Customers=0	0.180***	0.280***
	(0.003)	(0.009)
Suppliers=1, Customers=0	0.222***	0.300***
	(0.012)	(0.014)
Suppliers=0, Customers=1	0.340***	0.270***
	(0.024)	(0.014)
Suppliers=1, Customers=1	0.327***	0.353***
	(0.027)	(0.015)

*Note: Asterisks indicate significance levels of *1, **5 and ***10%. Source: Own Elaboration*

The results show that firms which do not collaborate with any partner are those which have the least likelihood to eco-innovate –only an 18% chance–. Firms which only collaborate with scientific partners, suppliers or customers have a probability of 28%, 22.1% and 34%, respectively. Firms which collaborate with "scientific partners and suppliers" increase the probability to 30% and those which collaborate with "scientific partners and customers" and "suppliers and customers" reduce the likelihood to innovate to 27% and 32,7%, respectively. Finally, the biggest effect on the probability of eco-innovation results from the simultaneous collaboration with the three types of partner, 35.3% chance. These estimations can be illustrated more clearly by examining them in a graphical representation. The marginal effects of different types of collaboration on the firms' likelihood to eco-innovation are shown in Figure 4.1.

Figure 4.1. Collaboration with scientific partners, suppliers and customers and the firms' likelihood to eco-innovate



Source: Own elaboration

5.4.2. Robust analysis

In addition to the common test for quality of fit and performance which support the acceptability of the estimates, we performed the robustness analysis of our principal panel random-effects regression; specifically, by running a fixed-effect panel estimation model. This model allowed us to monitor for biased firm-level heterogeneity (De Marchi, 2012; Haus-Reve et al., 2019; Marzucchi & Montresor, 2017). Table 4.4 shows the coefficients of using a balanced panel data set in all specifications. Although the sample was reduced from 10,918 to 4,238 firms, the effects of each type of individual collaboration are positive and significant, so H1-H3 are accepted. As in the random-effect model, single customer collaboration is the one which has the highest coefficient. The interaction term of the cooperation with two types of partners is negatively statistically significant, and only the cooperation with scientific partners, suppliers and customers is statistically positive, confirming the results for H4 obtained in the random model.

4.5. Discussion

We used data on 10,918 innovative Spanish firms to study how the collaboration agreements with external stakeholders impact the firms' likelihood to eco-innovate. Collaboration with external partners plays a crucial role in increasing firms' likelihood to eco-innovate because it is done either to pursue sustainable goals together (Behnam et al., 2018; Planko et al., 2019; Wei et al., 2020), to generate economies of scale orientated to reduced environmental impact (Melander & Pazirandeh, 2019; Melane-Lavado & Álvarez-Herranz, 2020; Pellegrini et al., 2019) or to increase the creation of value for society and itself (Cuerva et al., 2014; Ghisetti et al., 2015; Horbach et al., 2013). However, several empirical works have found contradictory results about the complementariness of specific combinations of external partners (Hofman et al., 2020; Kobarg et al., 2020; Melander, 2020; Rauter et al., 2019; Wei et al., 2020). To address this debate, we analysed all possible combinations of collaborations with "scientific partners, suppliers and customers" to examine whether the interaction between them generates complementary effects on firms' likelihood to eco-innovate or not. We analysed the data using a marginal effects approach and this analysis suggested important results for eco-innovation literature.

Table 4.4. Fixed Effect Model, eco-innovation. Balanced panel

Variables	(1) Coef. (S.E.)	(2) Coef. (S.E.)	(3) Coef. (S.E.)	(4) Coef. (S.E.)	(5) Coef. (S.E.)	(6) Coef. (S.E.)	(7) Coef. (S.E.)
Eco-innovation$_{t-1}$	1.028*** (0.029)	1.021*** (0.030)	1.018*** (0.030)	1.023*** (0.030)	1.027*** (0.296)	1.021*** (0.030)	1.021*** (0.030)
Scientific partner (STI)		0.540*** (0.052)	0.647*** (0.056)	0.669*** (0.540)		0.659*** (0.060)	0.696*** (0.061)
Suppliers		0.239*** (0.057)	0.455***(0.0783)		0.507*** (0.083)	0.319*** (0.084)	0.402*** (0.089)
Customers		0.282*** (0.067)		0.753*** (0.106)	0.415*** (0.065)	0.626*** (0.121)	0.832*** (0.140)
STI*Suppliers			-0.287*** (0.105)			-0.184 (0.113)	-0.366*** (0.128)
STI*Customers				-0.601*** (0.128)		-0.524*** (0.131)	-0.843*** (0.170)
Suppliers*Customers					-0.213* (0.119)	0.021 (0.125)	-0.504** (0.216)
STI*Suppliers*Customers							0.771*** (0.258)
Competitors	0.368*** (0.069)	0.084 (0.072)	0.120* (0.072)	0.111 (0.072)	0.215*** (0.071)	0.093 (0.072)	0.089 (0.072)
Subsidies	0.037 (0.055)	-0.041 (0.055)	-0.043 (0.055)	-0.043 (0.055)	0.008 (0.055)	-0.046 (0.056)	-0.049 (0.056)
R&D expenditures (log)	0.153*** (0.004)	0.147*** (0.004)	0.147*** (0.004)	0.148*** (0.004)	0.150*** (0.004)	0.146*** (0.004)	0.146*** (0.004)
Share of exports (%)	0.002** (0.001)	0.002** (0.001)	0.002** (0.001)	0.002** (0.001)	0.002** (0.001)	0.002** (0.001)	0.002** (0.001)
Firm size (log)	0.330*** (0.056)	0.300*** (0.056)	0.299*** (0.056)	0.303*** (0.056)	0.316*** (0.056)	0.300*** (0.056)	0.299*** (0.056)
Firm age (log)	0.091 (0.222)	0.163 (0.223)	0.169* (0.223)	0.169 (0.223)	0.108*** (0.022)	0.170 (0.223)	0.169 (0.223)
Manuf. (high technology)	0.140 (0.266)	0.072 (0.267)	0.086 (0.267)	0.073 (0.266)	0.106 (0.266)	0.073 (0.267)	0.059 (0.266)
Manuf. (med-high tech.)	0.190 (0.186)	0.213 (0.187)	0.204 (0.187)	0.216 (0.187)	0.209 (0.186)	0.215 (0.187)	0.215 (0.187)
Service (high technology)	-0.162 (0.207)	-0.154 (0.208)	-0.157 (0.208)	-0.146 (0.208)	-0.147 (0.207)	-0.147 (0. 207)	-0.150 (0.208)
Innovative Region	0.247*** (0.072)	0.235*** (0.073)	0.244*** (0.073)	0.227*** (0.073)	0.234*** (0.073)	0.232*** (0.073)	0.233*** (0.073)
Year	YES	YES	YES	YES	YES	YES	YES
Log Likelihood	-10122.719	-10007.328	-10012.528	-10004.502	-10061.192	-9995.288	-9990.826
Wald chi^2	4228.34(18)	4459.12 (21)	4448.72 (21)	4464.77 (21)	4351.39 (21)	4483.20 (24)	4492.12 (25)
Observations	30,199	30,199	30,199	30,199	30,199	30,199	30,199
Firms	4,238	4,238	4,238	4,238	4,238	4,238	4,238

*Note: Asterisks indicate significance levels of *1, **5 and ***10%. Source: Own Elaboration*

First, collaboration with any type of non-competitive partner – scientific partner, supplier or customer– increases the firms' likelihood to eco-innovate. This result confirms an extended point of view in eco-innovation literature, namely that collaboration is a key determinant of eco-innovation (Horbach, 2008; Mazzanti & Zoboli, 2009; De Marchi, 2012). In addition, our results show that customers are the most important partner for increasing firms' likelihood to eco-innovate. Firms could orientate their eco-innovation activities to introduce eco-friendly products that the customer can easily verify (De Marchi & Grandinetti, 2013). This orientation generates a lot of benefits, such as the changing of customers' mentality and improving the firms' image, but this could also limit other types of eco-innovations which would have a more critical impact on the environment before the product reaches the customer (Melander, 2018).

Second, multi-partner collaboration does not always generate complementary effects. The simultaneous existence of partial-complementary and substitutive effect can explain why the previous literature contains contradictory results (Hofman et al., 2020; Melander, 2020; Rauter et al., 2019; Wei et al., 2020). Our marginal analysis shows "scientific partners and suppliers" increases firm's likelihood to eco-innovate to a higher level than collaborate with only one of them. This positive effect supports studies which find positive effects (Bönte & Dienes, 2013; Kobarg et al., 2020; Melander, 2020), either because of a firm's increase in access to external resources or because the reduction of the transaction costs when tangible resources or new technologies are shared (Cainelli et al., 2012; Foster & Green, 2000; Johnsen, 2009; Steward & Conway, 1998).

Although it is true that the combination of both do not have a multiplicative or additive effect, only a partial complement effect from a marginal perspective, this can be the explanation for the negative results shown by several studies (Hofman et al., 2020; Marzucchi & Montresor, 2017; Mothe et al., 2018). A partial substitutive effect can be caused by the cost of coordination between the partners (Albort-Morant et al., 2018; Ghisetti et al., 2015), trust issues (González-Moreno et al., 2019; Melander & Pazirandeh, 2019) or the difficulty in aligning their interest (Ketata et al., 2015). The substitutive effects are clearer when we studied the combinations of customer collaboration with scientific partners (Kobarg et al., 2020; Mothe et al., 2018; Rauter et al., 2019) or suppliers (Hofman et al., 2020; Wei et al., 2020). In these cases, the firms' likelihood of eco-innovation is reduced in comparison with collaboration with customers alone.

Finally, only firms which collaborate with the three external partners can reach the maximum likelihood of eco-innovation. It is a partial complementary effect but it is the only combination which can overcome the effect of collaboration with customers. This result is in line with studies which have addressed the complementary effect from collaboration network and environment approaches. In these situations, the firms live in a community and are not seen as individuals, but rather members of a network which have sustainability goals in common (Folke, 2006; Dahl, 2014). Planko et al. (2019) and Wei et al. (2020) showed there are some industries in which this perspective is more relevant and could increase the likelihood of eco-innovation together. Moreover, being part of this network or environment could encourage firms to change their behaviour and values to become more environmentally friendly as a way of creating value for the community where the firms are located (Marcon et al., 2017).

4.6. Conclusions

Building on collaborative networks and open-eco innovation theory, this research set out to understand how collaboration agreements with different stakeholders such as scientific partners, suppliers, and customers increase the firms' likelihood of eco-innovation and whether their combination produces a complementary or substitutive effect. We examine the question empirically by steering the nature of the interaction between different combinations. Because of that we were able to show how firms' eco-innovation could benefit the most from external collaboration.

Our results offer a point of view which is able to unite both sides of the discussion about the complementary or substitutivity effect of external collaboration. We contribute to open eco-innovation and collaboration network theories by extending prior analyses and moving beyond the dichotomic debate by using a marginal analysis approach. This approach allows us to analyse the interactions, opening a window to discover mixed and partial interactive effects. Thus, we discovered that customer collaboration is what marginally increases a firm’s likelihood of eco-innovating the most and that the combination of this important partner with others, such as scientific partners or suppliers, generates partial substitutive effects. We also found that simultaneous collaboration with scientific partners and suppliers increases their individual impacts, generating a partial complementary effect, and that collaboration with all external partners can reach the highest level of firms’ likelihood to eco-innovate. In this way, we respond to recent calls which emerged in several eco-innovation literature reviews about the necessity of analysing the complementarity effect between external partners in depth (Dangelico, 2016; Del Río et al., 2016; Ehls et al., 2020; Johnsen, 2009).

These findings have important implications for firm managers but also for researchers and policy designers. First, business strategy and open innovation theory always point out the benefit of engagement in collaboration agreements with multiple external stakeholders on firms’ likelihood to eco-innovate (Melander & Pazirandeh, 2019; Pellegrini et al., 2019; Planko et al., 2019; Wei et al., 2020). Our results suggest that firms must consider carefully their partner selection, based on their business strategy (Ma et al., 2017). For example, simultaneous collaboration with scientific partners, suppliers, and customers increases the firms’ likelihood to eco-innovate while customer collaboration is what will marginally increase the firms' likelihood of eco-innovating.

We suppose that it is very likely that collaboration with customers will orientate firms’ activities to introduce eco-innovations that markets can easily recognise. Hence, knowing that firms’ resources are limited, we believe that this eco-innovation could brake others, which would have a more critical impact on the environment, such as on those related to the supply-chain efficiency or new technologies obtained from the collaboration with scientific partners and suppliers (De Marchi & Grandinetti, 2013). Based on this, we suggest that managers should align their collaborative agreements with those external stakeholders who better complement their objectives rather than establish a “catch-all” partnership strategy.

Second, methodologically our findings suggest the importance of introducing marginal difference analysis to estimate interaction terms between independent variables on non-linear models. Although interaction terms are used widely in applied econometrics, and many researchers know the correct way to interpret them, most applied researchers misinterpret the interaction term's coefficient (Ai & Norton, 2003; Buis, 2010). Thus, our work and that of others like the Kobarg et al. (2020)'s research, open a window in eco-innovation literature to expand and make more robust the studies about how determinants of firms' eco-innovation interact between them.

Third, our results suggest that public institutions need to create specific instruments such as public-supported R&D collaboration, subsidies or tax incentives to encourage firms to eco-innovate. As we report in our results, the standard innovation subsidies programme could not achieve this objective, so they have to be redefined. Moreover, public sponsored R&D collaboration could be the best way for institutions to develop an ecosystem in which sustainability goals are co-ordinately pursued together between different types of agents (Bengtsson & Kock, 2000; Folke, 2006; Dahl, 2014).

This study is not without limitations, and addressing them may open new research avenues. First, although this study focusses on the impact of external stakeholder engagement, we do not examine its interaction with internal dimensions – such as absorptive capacity, social capital or RSC strategy (Du et al., 2018; Hagedoorn & Wang, 2012; Ketata et al., 2015; Melander, 2018). It is undeniable that these dimensions would moderate the effect of multi-partner collaboration on firm's likelihood to eco-innovate and that is why we encourage tracking research to try to follow this lead to joint internal and external dimensions. Second, our data shows how external collaboration interacts in a developed country over a long period, but further analyses need to be done with samples from different countries and with more recent observations.

Specifically, we need to focus on firms from non-developed regions to be able to draw universally applicable conclusions (Hofman et al., 2020; Sanni, 2018). More recent observations could offer a new perspective of how firms' external collaboration is evolving as society is becoming aware of the importance of pursuing sustainable goals. Finally, the binary structure of our dependent variable limits our understanding of the quality and complexity of eco-innovations. Further investigations need to be done using, for example, the patents' relevance as a proxy or the quality of the eco-innovation, or other innovation surveys which analyse in-depth eco-innovation like the Mannheim Innovation Panel (Kobarg et al., 2020).

Taking these caveats into account, the results, nevertheless, provide considerable food for thought about the scope of external collaboration needed for firms to eco-innovate. Overall, the results supply new ideas about what types of external stakeholders are needed in order to maximise eco-innovation outputs and about whether firms need to consider different combinations of partners based on what their business and environmental strategies are.

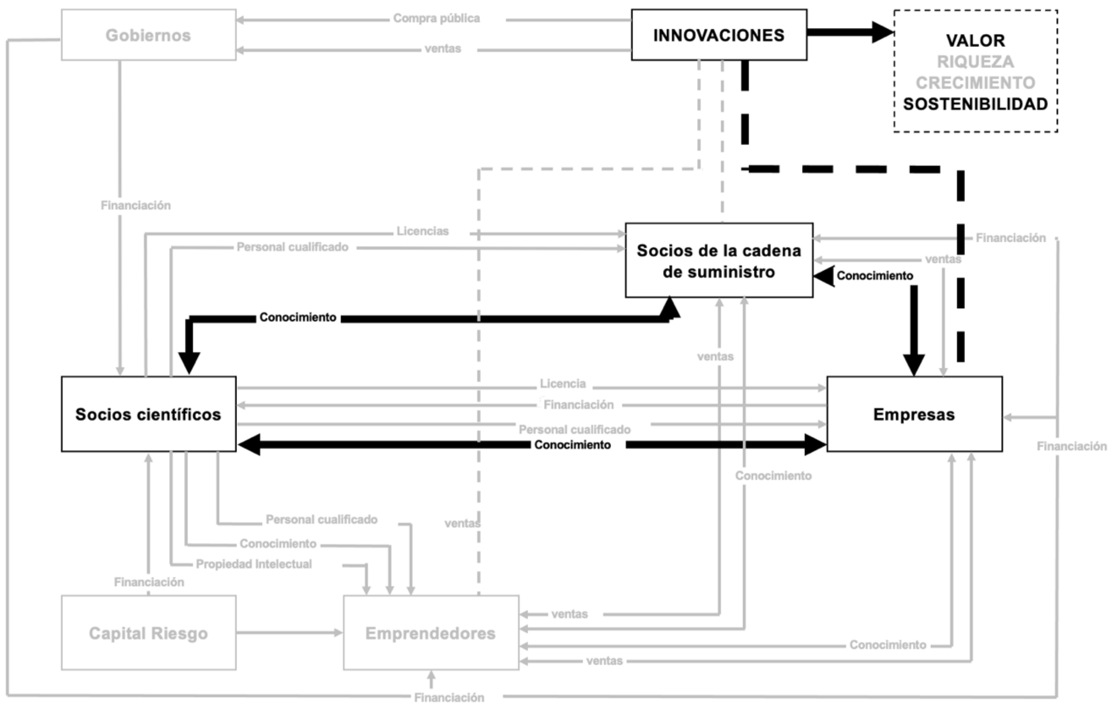
CAPÍTULO 5. DISCUSIÓN GENERAL

Aunque existe un amplio consenso sobre como la innovación es el principal impulsor del crecimiento económico (Aghion et al., 2021), todavía no se conoce en profundidad como se produce el fenómeno y cuáles son los mecanismos que se deben promover para aumentarlo (Lundvall, 2013). Durante mucho tiempo los países europeos han intentado superar la "paradoja europea" de ser líderes en la producción de conocimiento científico y no ser capaces de comercializarlo a través de nuevos productos o procesos (Fragkandreas, 2017). La razón de este problema se atribuye a varias causas como la falta de espíritu emprendedor, la baja competitividad y al mal diseño de las políticas públicas (Argyropoulou et al., 2019). Sin embargo, el problema ha sido tratar de analizar el fenómeno de la innovación desde una perspectiva sistémica (Rakas y Hain, 2019). Un sistema es un grupo de elementos interrelacionados que actúan de acuerdo a un conjunto de reglas para formar un todo unificado (Lundvall, 1992).

Nuevos enfoques como el del ecosistema de innovación ofrecen una visión más realista sobre el proceso innovador considerándolo el resultado de relaciones complejas no jerarquizadas que producen efectos complejos en la creación de valor (Adner, 2010; Jacobides et al., 2019; Grandstard & Holgersson, 2020). Esta perspectiva no rechaza los avances realizados por literaturas previas como la gestión de la innovación o los sistemas de innovación, sino que trata de adaptarlos para proponer una nueva síntesis que sirva de base para un nuevo tiempo en los estudios sobre innovación. Para ello, sintetiza conocimientos y responde a nuevas preguntas como: ¿Cuánto valor crea la colaboración de una empresa con un socio científico? ¿Cuál es la mejor combinación de socios para potenciar la innovación con objetivos medioambientales? ¿Qué efecto tiene la combinación de los programas de apoyo a la I+D por parte de distintos gobiernos? Responder a estas y otras pregunta es crucial para superar problemas como el de la paradoja europea.

Desde este punto de vista, esta tesis doctoral tiene como objetivo responder a la llamada realizada por Granstrand & Holgersson (2020, p. 3) para expandir los estudios de innovación analizando las relaciones, los artefactos y las actividades del ecosistema de innovación que mejor promueven la creación de valor. Para ello, nos hemos centrando en las relaciones complementarias y sustitutivas entre empresas, socios científicos y de la cadena de suministro. Estos agentes son los que están más relacionados con la innovación, la tecnología y las necesidades del mercado lo que los lleva a perseguir la creación de valor en todas sus decisiones (Adner & Kapoor, 2010). Para lograr este objetivo, en esta tesis doctoral hemos analizado diversas relaciones del ecosistema innovador que pueden ser representadas en el modelo conceptual propuesto en la introducción como muestra la Figura 5.1.

Figura 5.1. Relaciones del ecosistema de innovación analizadas



Fuente: Elaboración propia

En los siguientes apartados resumiremos los resultados principales de estas investigaciones, discutiremos sus implicaciones y limitaciones y ofreceremos una reflexión final.

5.1. Resumen de los resultados

5.1.1. Ecosistema innovador: El futuro de los estudios sobre innovación

En el Capítulo 2, revisamos la literatura sobre innovación desde las dos perspectivas teóricas más importantes de los últimos cuarenta años, los sistemas de innovación y los ecosistemas de innovación. Por un lado, los primeros argumentan que el concepto de “ecosistema” es solo una palabra de moda para consultores y medios (Oh et al., 2016). Por otro lado, los segundos explican que este concepto ofrece una perspectiva útil para comprender las complejas relaciones que produce la innovación (Ritala & Almpanopoulou, 2017). Este debate entre estas dos comunidades científicas ha producido que, en lugar de tratar de colaborar entre sí, hayan crecido por separado y en oposición (Faissal Bassis & Armellini, 2018; Rakas & Hain, 2019; Suominen et al., 2019). Mediante un análisis de la literatura relacionada con ambos conceptos, repasamos la evolución de ambas literaturas y mostramos las conexiones entre ellas. Gracias al análisis bibliométrico utilizado (Donthu et al., 2021), estudiamos 6.500 artículos científicos publicados en el periodo 1997-2021 y sus referencias citadas. De este primer estudio se pueden extraer las siguientes conclusiones:

En primer lugar, mostramos que los estudios sobre sistemas de innovación han dominado el campo desde la década de los 90 hasta el 2010 gracias a la perspectiva del sistema nacional de innovación y sus diversas variaciones. Algunas de ellas, como la perspectiva regional, fueron rápidamente adoptadas por los gobiernos europeos porque encajan perfectamente con su visión de la "Europa de las regiones", mientras que otros, como los "modelos de triple hélice", se han utilizado para centrarse en partes específica del subsistema de innovación (Chaminade et al., 2018). Sin embargo, a partir de mediados de la década pasada, estas perspectivas comenzaron a perder relevancia en favor de otros marcos como la innovación abierta o el de ecosistema innovador.

Segundo, descubrimos que mientras los sistemas de innovación están orientados a estudiar temas como la biotecnología, las patentes o las políticas públicas, los estudios sobre ecosistemas de innovación están más relacionados con temas como la sostenibilidad, la colaboración o el emprendimiento. Además, el análisis sobre el acoplamiento bibliográfico muestra la existencia de tres clústeres principales en los trabajos analizados: la literatura sobre sistema de innovación, la literatura sobre transiciones sostenibles y la literatura sobre el ecosistema innovador.

En tercer lugar, los resultados de este capítulo sugieren las posibles conexiones entre los tres clústeres principales. Los temas propuestos son: la gobernanza de los ecosistemas (Borras & Edler, 2014: p. 30; Könnölä et al., 2021; Thomas & Autio, 2020), la innovación con orientación medioambiental (Schot and Steinmuller, 2018; Yin et al., 2020; Hobarch et al., 2013) y la co-creación de valor (Grèzes et al., 2016; Adner, 2017; Carayannis et al., 2018). Los ecosistemas de innovación necesitan explorar el rol regulador de los gobiernos; la investigación sobre los determinantes de la innovación podría trasladarse a la innovación medioambiental y los análisis clásicos sobre los efectos de la colaboración podrían analizar la existencia de relaciones complementarias o sustitutivas en función de los agentes, artefactos y mecanismos utilizados para la creación de valor.

5.1.2. Co-creación de valor con socios científicos

En el Capítulo 3 analizamos las relaciones complementarias entre socios científicos y empresas en la co-creación de valor. La literatura previa ha abordado este tema como Colaboración Universidad-Industria o Relaciones Universidad-Industria, y su línea principal de argumentación es que esta relación tiene un impacto positivo en el desempeño tanto innovador como económico de las empresas (Vivas & Barge-Gil, 2015). Sin embargo, un análisis profundo de la literatura permite ver que los resultados no son siempre positivos y que existe una amplia variedad en los agentes analizados, los mecanismos utilizados y los resultados mostrados en los trabajos empíricos. Analizando 51 estudios y sus 173 resultados mostrados a través de un análisis de metarregresión, extraemos las siguientes conclusiones:

Primero, la mayoría de los estudios sobre la colaboración con socios científicos se ha centrado en la innovación en productos y patentes (Becker & Dietz, 2004; Fey & Birkinshaw, 2005; Nieto & Santamaría, 2010) y pocos son los que se han centrado en el objetivo final de la empresa, el desempeño económico (Caloghirou et al., 2001; Volpi, 2017). Además, descubrimos que en torno al concepto de “Universidad” se esconden todo tipos de organizaciones de investigación modernas (Aiello et al., 2019; Albahari et al., 2017; Biedenbach et al., 2018) como las Institutos de Investigación u otros tipos de Organizaciones de Investigación y Tecnología. Estos tres tipos de socios no tienen los mismos objetivos y la elección de uno u otro a la hora de innovar influye directamente en los resultados obtenidos. De esta forma, mostramos que, bajo un mismo tema, los académicos están analizando una amplia variedad de agentes, mecanismos y artefactos que explica la existencia de efectos mixtos (Brouwer & Kleinknecht, 1996; Arvanitis & Woerter, 2009, Di Maria et al., 2019).

En segundo lugar, gracias al análisis de metaregresión descubrimos la existencia de un sesgo de publicación en favor de los resultados positivos. La literatura sobre la colaboración entre socios científicos y empresas tiende a presuponer esta relación como un impulsor crucial de la innovación y esto ha podido ser la causa de que exista una tendencia a publicar solo resultados positivos y a la omisión de aquellos estudios que afirman lo contrario (Hewitt-Dundas et al., 2019). Este sesgo de publicación puede generar un problema al ocultar la existencia de resultados negativos o nulos que se deberían a la hora de diseñar las estrategias empresariales y las políticas públicas (Rothstein et al., 2006).

En tercer lugar, mostramos cómo la colaboración con socios científicos contribuye positivamente al desempeño de las empresas en términos técnicos y cómo a nivel económico estos efectos son menores y casi nulos. En concreto, los resultados más positivos se obtienen colaborando con Organizaciones de Investigación y Tecnología (RTOs) y cuando las empresas que participan no tienen un pasado innovador (Almeida et al., 2011). Estos resultados se pueden explicar por la existencia de rendimientos decrecientes en la interacción entre empresas y socios científicos siendo aquellas empresas que se encuentran en una fase inicial de colaboración las que más logran beneficiarse de compartir recursos con este tipo de socios.

5.1.3. Eco-innovación: Complementariedad entre socios externos

En el Capítulo 4 analizamos si la colaboración con socios científicos, proveedores y clientes aumenta la probabilidad de introducir innovaciones de carácter medioambiental en las empresas y si su combinación produce efectos complementarios o sustitutivos. La literatura previa ha abordado este tema analizando la cooperación con diferentes socios (De Marchi, 2012), pero no ha comparado las distintas combinaciones que se pueden producir ni la existencia de interacciones entre ellas (Dangelico, 2016). Analizando una muestra de 10.918 empresas españolas entre 2008–2016 mediante un análisis de efectos marginal, tratamos de responder a descubrir el efecto que produce colaborar con diferentes tipos de socios en un tipo de innovación crucial para la sociedad: las eco-innovaciones. De este trabajo extrajimos las siguientes conclusiones:

En primer lugar, nuestros resultados muestran que la colaboración con cualquier socio no-competitivo (socio científicos, proveedores o clientes) aumenta la probabilidad de eco-innovación de las empresas. Este resultado confirma un punto de vista extendido en la literatura sobre innovación acerca de los beneficios de la colaboración externa (Horbach, 2008; Mazzanti & Zoboli, 2009; De Marchi, 2012). En concreto, los clientes son el socio más importante para aumentar la probabilidad de eco-innovación de las empresas. Esto se debe a que las empresas orientan sus actividades de eco-innovación a introducir productos ecológicos que el cliente pueda verificar fácilmente (De Marchi & Grandinetti, 2013). Esta colaboración genera rápidamente muchos beneficios ya que permite, cambiar la mentalidad de los clientes y mejorar la imagen de las empresas, pero puede limitar el desarrollo de otro tipo de eco-innovaciones relacionadas con el proceso o los materiales que sean más difíciles de observar (Melander, 2018).

En segundo lugar, mostramos que la colaboración de múltiples socios no siempre genera efectos complementarios. Solo la combinación de los “socios científicos y proveedores”, aumenta la probabilidad de eco-innovación de la empresa a un nivel más alto que colaborar con solo uno de ellos. Este efecto positivo respalda estudios previos como Bönte & Dienes (2013), Kobarg et al. (2020) y Melander (2020). La causa de este impacto positivo se puede deber a que la empresa se beneficia del acceso a recursos externos relacionados con la innovación en proceso y en materiales y por la reducción de los costes de cuando se comparten recursos o nuevas tecnologías (Cainelli et al., 2012; Foster & Green, 2000; Johnsen, 2009; Steward & Conway, 1998).

Finalmente, nuestros resultados muestran que solo las empresas que colaboran con todos los tipos de socios llegan a alcanzar la probabilidad más alta de introducir una de eco-innovación. En estas situaciones, las empresas viven en un ecosistema con el que interaccionan y no actúan como individuos aislados si no como miembros de una comunidad con objetivos de sostenibilidad comunes (Folke, 2006; Dahl, 2014). Como Planko et al. (2019) y Wei et al. (2020) mostraron que esta perspectiva es más relevante en industrias verdes ya que la empresa tienen valores distintos y se encuentra muy interconectada con el resto de empresas con las que colaboran (Marcon et al., 2017).

5.2. Implicaciones

Esta tesis doctoral, tiene varias implicaciones prácticas para directivos, académicos y legisladores. En general, para todos ellos, enriquecemos la comprensión del concepto de ecosistema de innovación y les ofrecemos un análisis sobre la existencia de relaciones complementarias y sustitutivas entre los agentes clave del mismo: socios científicos, socios de la cadena de suministro y empresas. Este conocimiento les proporciona información útil para establecer mejor sus alianzas, retos de investigación y diseño de políticas públicas. En concreto, para cada uno de ellos, podemos ofrecer las siguientes implicaciones.

5.2.1. Implicaciones para los directivos

Para los directivos, esta tesis les ofrece una mejor comprensión de cómo la colaboración externa con otros agentes del ecosistema de innovación puede potenciar sus resultados, creando valor para ellos y para la sociedad. Durante los últimos años se ha podido observa cómo la literatura sobre innovación abierta ha ganado mucha relevancia entre los directivos. Sin embargo, estas teorías tienden a sobreestimar los resultados positivos derivados de la colaboración externa y a reducir los posibles resultados negativos. La perspectiva del ecosistema de innovación introduce el análisis de relaciones complementarias y sustitutivas ofreciendo una imagen más fiel de lo que sucede en el mundo real (Adner and Kapoor, 2010).

Para ellos, el Capítulo 1 les clarifica en qué consisten las dos literaturas principales sobre innovación y les ofrece una síntesis conceptual. Además, les muestra cómo las transiciones sostenibles juegan un papel clave en el mundo académico y les señala la necesidad de adaptar su modelo de negocio a este nuevo paradigma. Ejemplos de ellos son la agricultura sostenible o los modelos de nuevas formas de generación de energía para industrias locales. Estos resultados son muy importantes porque señalan la necesidad de reubicar la innovación empresarial hacia objetivos medioambientales. Algo que no solo es positivo en términos de valor para las empresas sino también para la sociedad.

El Capítulo 2 les muestra los resultados que obtendrán a partir de la colaboración con socios científicos. Los resultados desalientan la colaboración tradicional ya que se muestra cómo casi no consiguen aumentar el rendimiento económico de la empresa. De esta forma, las compañías deben reorientar su colaboración hacia socios científicos más centrados en desarrollar tecnología aplicada e innovaciones orientadas al mercado como los institutos de investigación y los laboratorios privados. Además, en este capítulo los directivos pueden ver cómo son aquellas empresas que no se definen como innovadoras las que mayores resultados obtienen de la colaboración con socios científicos. Son por tanto estas, las que deberían de buscar la colaboración de dichos agentes ya que les ayudan fácilmente a implentar los conocimientos técnicos existentes a sus productos.

Finalmente, el Capítulo 3 descubre los mejores socios externos para desarrollar innovaciones medioambientales. Con este trabajo mostramos que la colaboración con socios científicos y de la cadena de suministro producen los resultados más positivos. La combinación de clientes y proveedores o socios científicos produce efectos sustitutivos parciales, mientras que la colaboración con proveedores y socios científicos producen efectos positivos. A nivel individual es la colaboración con clientes la que mayores rendimientos produce ya que ofrece una oportunidad de generar y capturar mayor valor en el mercado a través del desarrollo de nuevos productos fácilmente identificables por el consumidor.

5.2.2. Implicaciones para los gobiernos

Para los diseñadores de políticas públicas, esta tesis les ofrece una mejor comprensión sobre cómo interactúan los agentes del ecosistema de innovación, cuáles son los principales tipos de relaciones y cómo pueden promover estas relaciones para impulsar la innovación. Aunque durante varias décadas, la literatura sobre sistemas de innovación ha ofrecido a los gobiernos una gran ayuda a la hora de entender el fenómeno de la innovación, posiblemente se haya sobreestimado el papel que desempeña el estado. La perspectiva del ecosistema de innovación les ofrece un concepto más preciso de lo que sucede en el mundo real y cuáles pueden ser las acciones que hay que promover para aumentar los resultados.

Para ellos, nuestro primer capítulo ofrece un marco teórico a través del cual pueden diseñar políticas capaces de incentivar la innovación; pero, si bien llevan años tratando de hacerlo, se puede afirmar que los resultados que han obtenido son más humildes de lo que esperaban. La perspectiva del ecosistema innovador ofrece un punto de vista más realista sobre cómo se desarrolla la innovación tratando de centrarse en la iniciativa privada en lugar de tratar de dar forma al proceso de innovación.

Nuestro segundo capítulo muestra que los socios científicos todavía no tienen objetivos plenamente alienados con los de las empresas. Es por ello muy importante que la administración desarrolle un corpus legislativo nuevo orientado a promover la colaboración universidad-empresa generando los incentivos necesarios para promover esta conexión. Además, nuestros resultados muestran que son aquellas empresas no-innovadoras las que más se benefician de esta colaboración lo que incrementa exponencialmente las empresas que se podrían beneficiar de esta colaboración y, por tanto, se deben establecer los programas necesarios para promoverla.

Finalmente, para los gobiernos, mostramos cuales deben ser las uniones y colaboraciones que se deben fomentar a través de políticas públicas si queremos aumentar la innovación con fines medioambientales. En concreto, el desarrollo de proyectos de innovación que tengan en cuenta a todos los agentes del ecosistema innovador o aquellos orientados a colaborar únicamente con clientes.

5.2.3. Implicaciones para los académicos

Para los académicos, esta tesis les ofrece avances metodológicos y teóricos significativos con los que analizar el fenómeno de la innovación. Los estudios de innovación llevan años tratando de entender cómo se produce la innovación desde un punto de vista sistémico. Sin embargo, como hemos demostrado, esta es un proceso más orgánico, basado en la interacción de agentes autónomos no controlados jerárquicamente. Para los académicos, esta perspectiva les ofrece un mejor enfoque a la hora de comprender y estudiar el fenómeno de la innovación.

El Capítulo 2 proporcionan tres contribuciones principales a ambas comunidades académicas. En primer lugar, aunque los intentos anteriores han tratado de analizar los vínculos entre los estudios sobre los ecosistema de innovación y los sistemas de innovación, no han analizado en profundidad el acoplamiento bibliográfico. En nuestra investigación, hemos descubierto por primera vez la importancia de las innovaciones con objetivos medio-ambientales. Esta es una contribución importante de nuestro artículo en comparación con análisis anteriores como el realizado por Faissal Bassis & Armellini (2018) y Suominen et al. (2019). En segundo lugar, nuestro enfoque bibliométrico puede ayudar a identificar los puentes necesarios entre ambas teorías y crear una nueva síntesis, como sugieren Rakas & Hain (2019: 19) integrando también otras literaturas como la innovación abierta y los ecosistemas emprendedores.

El Capítulo 3 muestra a los académicos cuán importante es medir el resultado económico de las colaboraciones con socios científicos. De esta forma, se podría conocer mejor los determinantes de la paradoja europea y tratar de resolverla a través de un análisis de mejores prácticas centrándose en la creación de valor. Esto solo se puede hacer si se analiza desde una perspectiva de ecosistema que entienda que la colaboración con socios científicos no siempre genera efetos positivos, sino que es algo que depende de los agentes implicados, los mecanismos y artefactos utilizados.

Finalmente, los académicos deben comprender la importancia de analizar la colaboración con socios externos de manera individual como muestra el Capítulo 4. No basta con dar cuenta del número de sus socios como hacen trabajos previos o considerar la colaboración como una variable dicotómica, sino que se debe avanzar en el estudio de los efectos complementarios o sustitutivos que cada tipo de socio genera. Este enfoque centrado en la naturaleza de los tipos de socios les da a los académicos una mejor comprensión de cuáles son los efectos que deben analizar para promover la eco-innovación.

5.3. Limitaciones

Aunque hemos tratado de aplicar la máxima rigurosidad posible en cada uno de los capítulos de la tesis doctoral, cada capítulo sufre ciertas limitaciones que es necesario que nuestros lectores conozcan.

El Capítulo 2 tiene dos limitaciones principales. Primero, el conjunto de datos se recopiló con un protocolo que excluye otras versiones de "ecosistemas" como "ecosistemas de negocios", "ecosistemas de conocimiento" o "ecosistemas de plataforma" (Autio & Thomas, 2022). Esto se debe a que nuestro protocolo se centra en la perspectiva de la innovación y ha excluido otros más centrados en agentes emprendedores o contextos de innovación abierta. Las futuras revisiones de la literatura podrían explorar este lugar oculto para descubrir nuevos objetivos de investigación para fusionar corrientes de literatura altamente relacionadas. En segundo lugar, el aumento general en el número de referencias en la literatura académica puede haber creado algunos sesgos en los resultados a favor de etiquetas de moda relacionadas con los Ecosistemas de Innovación.

En segundo lugar, el Capítulo 3 sobre la colaboración entre socios científicos y empresas nos ayuda a comprender que los métodos cuantitativos habituales ocultan el mecanismo dentro de la colaboración pero se debe avanzar hacia análisis mixtos que puedan abordar simultáneamente los aspectos cuantitativos y cualitativos para analizar los efectos reales de esta colaboración. (Christensen, 2011; Ghisetti et al., 2015; Ketata et al., 2015). Estos enfoques tienen la oportunidad de analizar la heterogeneidad producida por diferentes socios científicos más allá de nuestra clasificación. Además, sería interesante saber, qué diferencias se producen entre las universidades técnicas y las normales, o si la universidad no juega un papel crucial en los ecosistemas de innovación debido a su falta de flexibilidad (Melander, 2020).

En tercer lugar, el Capítulo 4 presenta algunas limitaciones como por ejemplo, que no examinamos la interacción con dimensiones internas de las empresas, como la capacidad de absorción, el capital social o la estrategia de RSC (Du et al., 2018; Hagedoorn & Wang, 2012; Ketata et al., 2015; Melander, 2018). Es innegable que estas dimensiones tendrán un efecto moderador en la probabilidad de introducir eco-innovaciones y es por eso que alentamos a las investigaciones futuras a considerar la combinación entre las dimensiones internas y externas.

5.4. Investigaciones futuras

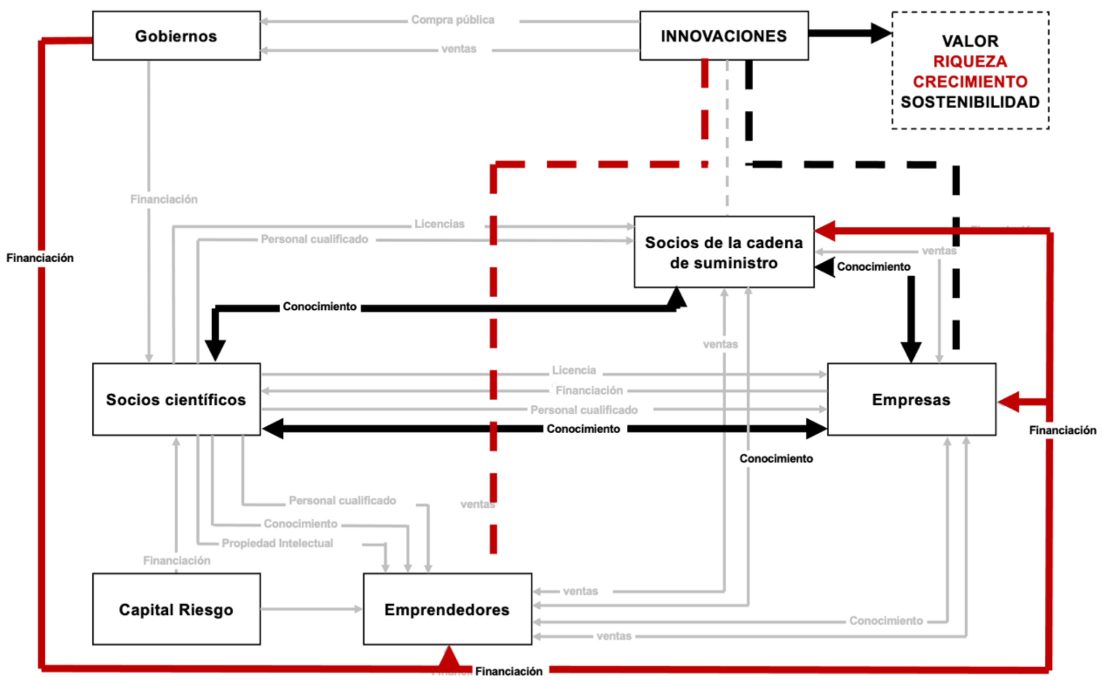
El objetivo de esta tesis es analizar las relaciones de complementariedad y sustitución entre los principales actores de los ecosistemas de innovación. La principal limitación que sufre este trabajo es que como explicamos en la introducción, el análisis de todas las relaciones posibles sería un trabajo de varias vidas, por lo que hemos decidido abordar este reto centrándonos en las relaciones centrales entre las empresas, sus socios científicos y los de la cadena de suministro. A partir de esta tesis se abren otras líneas de trabajo futuro en las que se analizará el papel que juegan otras interacciones clave del ecosistema innovador.

En primer lugar**,** la existencia de relaciones complementarias y sustitutivas entre distintitos gobiernos. En cada nivel institucional (regional, nacional y supranacional), los distintos gobiernos han diseñado e implementado programas de fomento a la innovación. Estos programas ya han sido ampliamente estudiados a nivel individual (Zúñiga-Vicente et al., 2014), pero todavía no se han analizado suficientemente la existencia de efectos complementarios o sustitutivos entre los programas de diferentes instituciones y los resultados que producen en la innovación empresarial. Una futura línea de investigación pretende abordar esta cuestión basándose en el enfoque del llamado *policy mix* (Flanagan et al., 2011).

En segundo lugar, analizar las relaciones que existen entre nuevos mecanismos de financiación, el capital riesgo y los emprendedores. España es uno de los países con los niveles de emprendimiento más bajos de Europa occidental (Leendertse et al., 2021), las políticas clásicas no han conseguido aumentar la competitividad de las empresas y es por eso que se ha decidido crear nuevos programas de apoyo centrados en las startups innovadoras con posibilidad de escalar. Estos programas de apoyo se instrumentalizan a través de los conocidos como préstamos participativos, un mecanismo híbrido entre capital y duda. Conocer si estas ayudas complementan o sustituyen el financiamiento privado dado por el capital riesgo y cuáles son los resultados que obtienen es clave para los programas europeos que los van a potenciar (Bertoni et al., 2019).

Finalmente, teniendo en cuenta este trabajo y los siguientes, pensamos que seremos capaces de analizar las principales relaciones complementarias y sustitutivas del ecosistema innovador como muestra la Figura 5.2.

Figura 5.2. Relaciones del ecosistema de innovación analizado en la tesis incluyendo futuras líneas de investigación



Fuente: Elaboración propia

5.5. Reflexiones finales

Con esta tesis doctoral demostramos que considerar las relaciones complementarias y sustitutivas del ecosistema innovador es crucial para entender completamente el fenómeno de la innovación. En el Capítulo 2 ofrecimos un marco teórico solido para conectar esta perspectiva con la literatura previa y servir como base para futuras investigaciones. En el Capítulo 3 analizamos la relación entre socios científicos y empresas y cómo los resultados de esta combinación pueden variar en función de los agentes, mecanismos y artefactos analizados. Por último, siguiendo una de las líneas abiertas en el segundo capítulo, en el Capítulo 4 analizamos cómo la eco-innovación está influenciada por la colaboración con socios externos y cómo estos interaccionan entre sí.

Esperamos que estos trabajos empíricos inspiren futuras investigaciones académicas centradas en analizar la innovación más allá de los enfoques clásicos y mejoren así nuestro conocimiento sobre cómo se produce este fenómeno crucial para la sociedad. También esperamos que tanto profesionales como gobiernos consideren en su toma de decisiones el conocimiento que hemos aportado sobre el ecosistema de innovación, la co-creación de valor y la innovación medioambiental y la forma en la que las interacciones entre los diversos agentes del ecosistema moldean estos resultados.

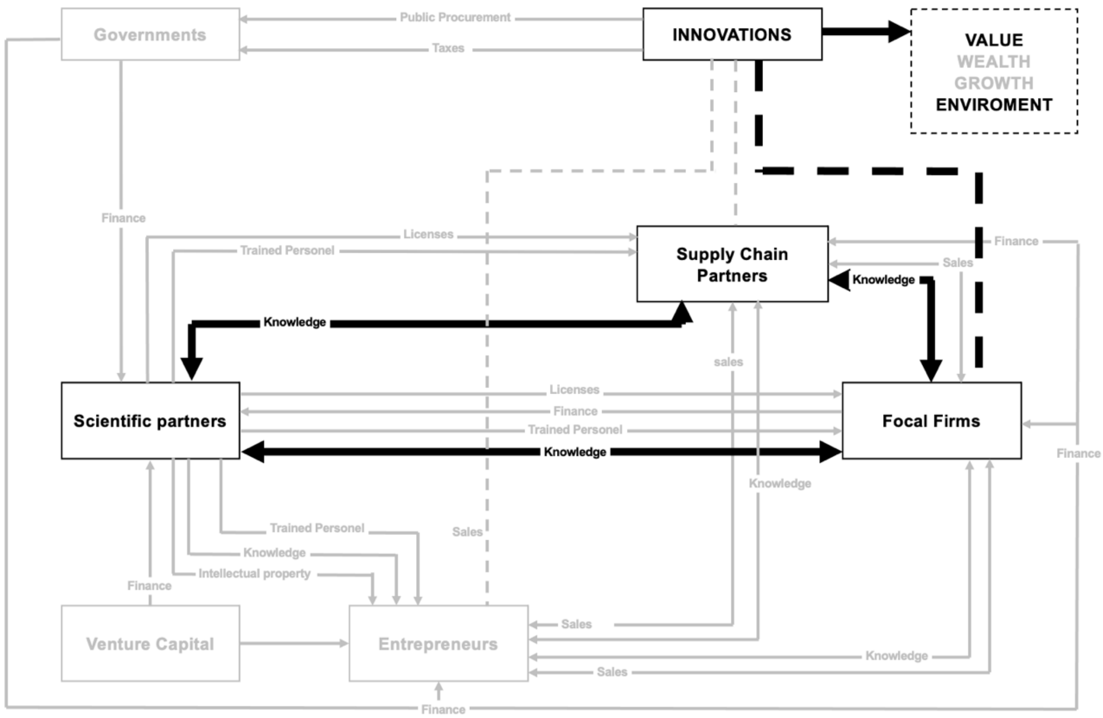
CHAPTER 5. GENERAL DISCUSSION

Although there is a broad consensus on that innovation is the main driver of economic growth (Aghion et al., 2021), it is not yet known in depth how the phenomenon occurs nor which mechanisms should be promoted to increase it (Lundvall, 2013). For a long time, European countries have tried to overcome the "European paradox" of being leaders in producing scientific knowledge yet not being able to market it via new products or processes (Fragkandreas, 2017). This problem is attributed to various causes such as the lack of an entrepreneurial spirit, low competitiveness and the poor design of public policies (Argyropoulou et al., 2019). However, the problem has been trying to analyse the phenomenon of innovation from a systemic perspective (Rakas & Hain, 2019). A system is a group of interrelated elements that act according to a set of rules to form a unified whole (Lundvall, 1992).

New approaches such as the innovation ecosystem offer a more realistic view of the innovative process, considering it the result of complex non-hierarchical relationships that exert complex effects on value creation (Adner, 2010; Jacobides et al., 2019; Grandstard & Holgersson, 2020). This perspective does not reject the advances made by previous literature, such as innovation management or innovation systems, but tries to adapt them and to propose a new synthesis which serves as the basis for a new era in innovation studies. To do this, it synthesises knowledge and answers new questions such as: How much value does collaboration between a company and a scientific partner create? What is the best combination of partners to promote innovation with environmental objectives? What effect produces the combination of R&D support programmes by different governments? Answering these and other questions is crucial to overcoming problems such as the European paradox.

From this point of view, this thesis aims to respond to the call made by Granstrand & Holgersson (2020, p. 3) to expand innovation studies by analysing the relationships, artefacts and activities of the innovation ecosystem that best promote innovation and value creation. To do this, we have focused on the complementary and substitutive relationships among firms, scientific and supply chain partners. These agents are most closely-related to innovation, technology and market needs, which leads them to pursue value creation in all their decisions (Adner & Kapoor, 2010). To achieve this goal, in this thesis, we have analysed various relationships of the innovation ecosystem that can be represented in the conceptual model proposed in the introduction, as shown in Figure 5.1.

Figure 5.1. Relations of the innovation ecosystem analysed in the dissertation



Source: Own elaboration

In the following sections we will summarize the main results of these investigations, discuss their implications and limitations, and offer a final reflection.

5.1. Overview of the main results

5.1.1 Innovation Ecosystem: The Future of the Innovation Studies

Chapter 2 reviews the innovation literature from the two most important theoretical perspectives of the last forty years, innovation systems and innovation ecosystems. On the one hand, the former argues that the concept of "ecosystem" is just a buzz-word for consultants and the media (Oh et al., 2016). On the other hand, the latter explains that this concept offers a useful perspective for understanding the complex relationships that innovation produces (Ritala & Almpanopoulou, 2017). This debate between these two scientific communities has, instead of collaborating, caused them to grow separately and in opposition (Faissal Bassis & Armellini, 2018; Rakas & Hain, 2019; Suominen et al., 2019). By analysing the literature related to both concepts, we review the evolution of both literature streams and show their connections. Thanks to the bibliometric technique used (Donthu et al., 2021), we analysed 6,500 scientific articles published in 1997-2021, and their cited references. The following conclusions can be drawn from this first chapter.

First, we show that innovation systems studies have dominated the field from the 1990s to 2010, thanks to the perspective of the national innovation system and its numerous variations. Some of them, like the regional perspective, were quickly adopted by European governments because they fit perfectly within their vision of the “Europe of the regions", while others, such as the "triple helix models", have been used to focus on specific parts of the innovation subsystem (Chaminade et al., 2018). However, starting in the middle of the last decade, these perspectives began to lose relevance in favour of other frameworks such as open innovation and the innovation ecosystem.

Second, we discovered, that while the innovation systems are oriented to study topics such as biotechnology, patents or public policies, studies on innovation ecosystems are more related to topics such as sustainability, collaboration or entrepreneurship. In addition, our analysis of the bibliographic coupling shows the existence of three main clusters in the analysed works: the literature on the innovation system, on sustainable transitions and on innovation ecosystems.

Third, the results of this chapter suggest the possible connections between the three main clusters. The proposed topics are ecosystem governance (Borras & Edler, 2014: p. 30; Könnölä et al., 2021; Thomas & Autio, 2020), environmentally oriented innovation (Hobarch et al., 2013; Schot & Steinmuller, 2018; Yin et al., 2020) and co-creation of value (Grèzes et al., 2016; Adner, 2017; Carayannis et al., 2018). Innovation ecosystems need to explore the regulatory role of governments, research on the determinants of innovation could be transferred to environmental innovation, and the classic analyses of the effects of collaboration could analyse the existence of complementary or substitutive relationships, depending on the agents, artefacts and mechanisms used to create value.

5.1.2. Co-creation of value with scientific partners

Chapter 3 analyses the complementary relationships between scientific partners and companies in value co-creation. Previous literature has addressed this topic as *University-Industry Collaboration* or *University-Industry Relations*, and its main line of argument is that this relationship positively impacts both the innovative and economic performance of companies (Barge-Gil & Vivas, 2015). However, a thorough analysis of the literature allows us to see that the results are not always positive and that there is a wide variety in the agents analysed, the mechanisms used and the results shown in the empirical works. Analysing 51 studies and their 173 results shown through a meta-regression analysis, we draw the following conclusions:

First, most studies on collaboration with scientific partners have focused on innovation in products and patents (Becker & Dietz, 2004; Fey & Birkinshaw, 2005; Nieto & Santamaría, 2010), and few have focused on the main goal of the firm, its economic performance (Caloghirou et al., 2001; Volpi, 2017). In addition, we discovered that all kinds of modern research organizations are hidden in the concept of "University" (Albaharti et al., 2017; Biedenbach et al., 2018; Aiello et al., 2019), such as Research Institutes and other types of research and technology organizations. These three types of partners do not have the same objectives, and the choice of one or the other when innovating directly influences the results obtained. In this way, we show that, under the same theme, academics analyse various agents, mechanisms and artefacts that explain the existence of mixed effects (Brouwer & Kleinknecht, 1996; Arvanitis & Woerter, 2009, Di Maria et al., 2019).

Second, using the meta-regression analysis, we discovered the existence of a publication bias in favour of positive results. The literature on collaboration between scientific partners and companies tends to assume this relationship as a crucial driver of innovation, and this may have been the cause of the tendency to publish only positive results and omission of those studies that affirm the opposite (Hewitt-Dundas et al., 2019). This publication bias can generate a problem by hiding the existence of negative or null results that should be used when designing business strategies and public policies (Rothstein et al., 2006).

Third, we show how collaboration with scientific partners contributes positively to the performance of companies in technical terms, and that, at an economic level, these effects are minor and almost null. Specifically, the most favourable results are obtained by collaborating with Research and Technology Organizations (RTOs). and when the participating companies do not have an innovative past (Almeida et al., 2011). These results can be explained by diminishing returns in the interaction between companies and scientific partners with those companies that are in an initial phase of collaboration -being the ones that most benefit from sharing resources with this type of partner.

5.1.3. Eco-innovation: Complementarity among external partners

Chapter 4 analyses whether collaboration with scientific partners, suppliers and customers increases the probability of introducing environmental innovations in companies and whether their combination produces complementary or substitutive effects. Previous literature has addressed this issue by analysing cooperation with different partners (De Marchi, 2012) but has not compared the different combinations that can occur or the existence of interactions between them (Dangelico, 2016). Analysing a sample of 10,918 Spanish companies between 2008 and 2016 through a marginal effects analysis, we tried to discover the effect produced by collaborating with different types of partners in a crucial innovation for society: eco-innovations. From this work, we drew the following conclusions:

First of all, our results show that collaboration with any non-competitive partner (scientific partner, supplier or client) increases the probability of eco-innovation of companies. This result confirms a widespread view in the innovation literature regarding the benefits of external collaboration (Horbach, 2008; Mazzanti & Zoboli, 2009; De Marchi, 2012). Specifically, customers are the most important partner for increasing the probability of eco-innovation of companies. Companies direct their eco-innovation activities to introduce ecological products that the customer can easily verify (De Marchi & Grandinetti, 2013). This collaboration quickly generates many benefits since it allows changing the mentality of customers and improving the image of companies. However, it can limit the development of other types of eco-innovations related to the process or materials, which are more difficult to observe (Melander, 2018).

Second, we show that the collaboration of multiple partners does not always generate complementary effects. Only the combination of the "scientific partners and suppliers", increases the probability of eco-innovation of the company to a higher level than collaborating with only one of them. This positive effect supports previous studies such as Bönte & Dienes (2013), Kobarg et al. (2020) and Melander (2020). The cause of this positive impact may be because the company benefits from access to external resources related to innovation in process and materials and due to a reduction in costs when resources or new technologies are shared (Foster & Green, 2000; Johnsen, 2009; Steward & Conway, 1998; Cainelli et al., 2012).

Finally, our results show that only companies collaborating with all types of partners have the highest probability of introducing an eco-innovation. In these situations, companies live in an ecosystem with which they interact, and do not act as isolated individuals but as members of a community with common sustainability goals (Folke, 2006; Dahl, 2014). As Planko et al. (2019) and Wei et al. (2020) showed, this perspective is more relevant in green industries, since the companies have different values and are highly interconnected with the rest of the companies with which they collaborate (Marcon et al., 2017).

5.2. Implications

This dissertation has several practical implications for managers, academics and governments. In general, for all of them, we enrich the understanding of the innovation ecosystem concept and offer an analysis of the existence of complementary and substitutive relationships between its key agents: scientific partners, supply-chain partners and companies. This knowledge provides them with useful information for establishing alliances, research challenges and public policy design. Specifically, for each of them, we offer the following implications.

5.2.1. Implications for managers

This dissertation offers managers a better understanding of how external collaboration with other agents in the innovation ecosystem can enhance their results, creating value for them and society. In recent years, it has been possible to observe how the literature on open innovation has gained much relevance among managers. However, these theories tend to overestimate the positive results derived from external collaboration and reduce the possible negative results. The perspective of the innovation ecosystem introduces the analysis of complementary and substitutive relationships, offering a more faithful image of what happens in the real world (Adner and Kapoor, 2010).

Chapter 1 clarifies the two main literature streams on innovation and offers them a conceptual synthesis. In addition, it shows them how sustainable transitions play a key role in the academic world and points out the need to adapt their business model to this new paradigm. Examples of them are sustainable agriculture and models of new forms of energy generation for local industries. These results are important because they indicate the need to reorient business innovation towards environmental objectives - something that is not only positive in terms of value for companies but also for society.

Chapter 2 shows the results they will obtain from collaborating with scientific partners. The results discourage collaboration since it hardly manages to increase the economic performance of the company. In this way, companies must reorient their collaboration with scientific partners to those more focused on developing applied technology and market-oriented innovations, such as research institutes and private laboratories. In addition, in this chapter, managers can see how those companies that do not define themselves as innovative are the ones that obtain the greatest positive results from collaboration with scientific partners. Therefore, these are the ones that should promote the collaboration of these agents since they easily help them integrate existing technical knowledge into their products.

Finally, Chapter 3 reveals the best external partners to develop environmental innovations. This investigation shows that collaboration with scientific and supply chain partners produces the most positive results. The combination of clients and suppliers or scientific partners produces partial substitution effects, while the collaboration with suppliers and scientific partners produces positive effects. At an individual level, collaboration with clients produces the greatest returns since it offers an opportunity to generate and capture greater value in the market through the development of new products easily identifiable by the consumer.

5.2.2. Implications for governments

For policymakers, this dissertation offers a better understanding of how the agents of the innovation ecosystem interact, what the main types of relationships are, and how they can promote these relationships to drive innovation. Although, for several decades, the literature on innovation systems has offered governments great help in understanding the phenomenon of innovation, the role of the state may have been overestimated. The perspective of the innovation ecosystem offers them a more precise concept of what happens in the real world and what actions can be promoted to increase results.

For them, the first chapter offers a theoretical framework to design policies that encourage innovation. Although they have been trying to do it for years, it can be affirmed that their results are humbler than expected. The innovation ecosystem perspective offers a more realistic view of how innovation develops by focusing on private initiatives rather than trying to shape the innovation process.

Our second chapter shows that the scientific partners do not yet have objectives fully aligned with those of the companies. Therefore, the administration must develop a new legislative corpus to promote university-business collaboration, generating the necessary incentives to promote this connection. In addition, our results show that non-innovative companies are the ones that benefit the most from this collaboration, which exponentially increases the number of companies that could benefit from this collaboration. Therefore, the necessary programmes must be established to promote this.

Finally, our third chapter reveals the best external partners for developing environmental innovations. For governments, we show which unions and collaborations should be promoted through public policies if we want to increase innovation for environmental purposes.

5.2.3. Implications for academics

This thesis offers academics significant methodological and theoretical advances to analyse the phenomenon of innovation. Innovation studies have spent years trying to understand how innovation occurs from a systemic point of view. However, as we have shown, this is a more organic process based on the interaction of autonomous agents not hierarchically controlled. For academics, this perspective offers a better approach to understanding and studying the phenomenon of innovation.

Our first chapter provides three main contributions to both academic communities. First, although previous attempts have tried to analyse the links between IE and SI studies, they have not analysed the bibliographic coupling in depth. In our research, we have discovered the importance of innovations with environmental objectives for the first time. This is an important contribution of our article compared to previous analyses such as the one by Faissal Bassis & Armellini (2018) and Suominen et al. (2019). Second, our bibliometric approach can help identify the necessary bridges between both theories and create a new synthesis, as Rakas & Hain (2019, p. 19) suggest, also integrating other literature streams such as open innovation and entrepreneurial ecosystems.

Beginning with our second chapter, scholars should understand how important measuring the economic outcome of collaborations with scientific partners is. In this way, it would be possible to understand the determinants of the European paradox better and try to resolve it through an analysis of best practices focusing on value creation. This can only be done if it is analysed from an ecosystem perspective that understands that collaboration with scientific partners does not always generate positive effects but is something that depends on the agents involved, and the mechanisms and artefacts used.

Finally, beginning with our third chapter, scholars need to understand the importance of individually looking at collaboration with external partners. It is not enough to account for the number of partners as previous works do or consider collaboration as a dichotomous variable. If not, progress should be made in studying complementary or substitute effects for each type of partner. This focus on the nature of partner types gives scholars a better understanding of what effects they need to analyse to promote eco-innovation.

5.3. Limitations

Although we have tried to apply the maximum possible rigour in each part of the thesis, each chapter suffers from certain limitations that our readers need to be aware of.

Chapter 1 has two main limitations. First, the data set was collected with a protocol that excludes other versions of "ecosystems" such as "business ecosystems", "knowledge ecosystems" and "platform ecosystems" (Autio & Thomas, 2022). This is because our protocol focuses on the innovation perspective and has excluded others more focused on entrepreneurial agents or open innovation contexts. Future literature reviews could explore these hidden areas to uncover new research targets for merging highly related streams of literature. Second, the general increase in the number of references in the academic literature may have created some bias in the results in favour of trendy labels related to “innovation ecosystems”.

Second, our study of the collaboration between scientific partners and companies helps us understand that the usual quantitative methods hide the mechanism within the collaboration. We must move towards mixed analyses that can simultaneously address the quantitative and qualitative aspects to analyse the real effects of this collaboration (Christensen, 2011; Ghisetti et al., 2015; Ketata et al., 2015). These approaches have the opportunity to analyse the heterogeneity produced by different scientific partners beyond our classification. In addition, it would be interesting to know the difference between technical and normal universities or if the university does not play a crucial role in innovation ecosystems due to its lack of flexibility (Melander, 2020).

Third, in our study, several lines of research have been opened; for example, we did not examine the interaction with internal dimensions of companies, such as absorption capacity, social capital or CSR strategy (Hagedoorn & Wang, 2012; Ketata et al., 2015; Melander, 2018; Du et al., 2018). Undeniably, these dimensions will moderate the probability of introducing eco-innovations, which is why we encourage future research to consider the combination of internal and external dimensions.

5.4. Future research

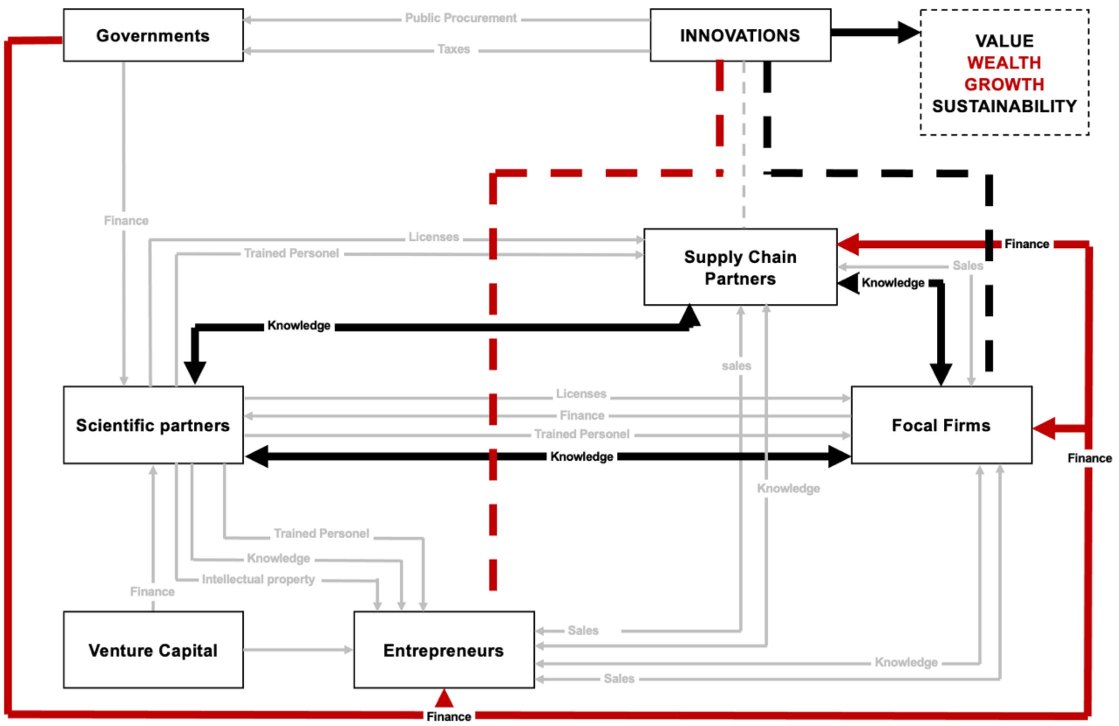
This thesis aims to analyse the relations of complementarity and substitution among the main actors of innovation ecosystems. The main limitation of this work is, as we explained in the introduction, the analysis of all possible relationships would be the work of several lifetimes, so we decided to address this challenge by focusing on the central relationships among companies, their scientific partners and the supply chain. This thesis enables the opening of other lines of future work in analysing the role played by other key interactions in the innovation ecosystem.

Analysing the complementary and substitute relationships between different governments. Different governments have designed and implemented programs to promote innovation at each geographical level (regional, national and supranational). These programs have already been extensively studied at the individual level (Zúñiga-Vicente et al., 2014). However, the existence of complementary effects between the programs of different institutions and the results they produce in business innovation has not yet been sufficiently analysed. A future line of research aims to address this question based on a policy mix perspective (Flanagan et al., 2011).

Analysing the relationships between new financing mechanisms, venture capital and entrepreneurs. Spain is one of the countries with the lowest levels of entrepreneurship in Western Europe (Leendertse et al., 2021); classic policies have not managed to increase companies' competitiveness, which is why it has been decided to create new entrepreneurship programs: support focused on innovative startups with the possibility of scaling. These support programs are realized through what are known as participating loans, a hybrid mechanism between capital and loans. Knowing if these aids complement or replace private financing given by venture capital, and what results they obtain is key for the European programs that will promote them (Bertoni et al., 2019).

Finally, considering this work and the following ones, we think we will be able to analyse the innovation ecosystem's main complementary and substitutive relationships, as shown in Figure 5.2.

Figure 5.2. Relations of the innovation ecosystem anaylsed in the dissertation including future research lines



Source: Own elaboration

5.5. Final thoughts

In this doctoral thesis, it is demonstrated that considering the complementary and substitutive relationships of the innovation ecosystem is crucial to fully understanding the phenomenon of innovation. Chapter 2 offers a solid theoretical framework to connect this perspective with previous literature and serve as a basis for future research is presented. Chapter 3 analyses the relationship between scientific partners and companies and how the results of this combination can vary depending on the agents, mechanisms and aspects is analysed. Finally, following one of the lines opened in the second chapter, Chapter 4 analyses how eco-innovation is influenced by collaboration with external partners and how they interact with each other is analysed.

It is hoped that these empirical works inspire future academic research which looks at innovation beyond classical approaches and thus improves our understanding of how this crucial phenomenon for society occurs. It is further hoped that both professionals and governments consider the knowledge we have provided about the innovation ecosystem, the co-creation of value and environmental innovation and how the interactions between the various agents of the ecosystem shape these results in their decision-making.

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APPENDIX

Table 2.A. Keywords and Search Strings

Category	Keywords
University	Universit* OR HEI* OR Higher Education OR Academ* OR Research*
Industry	Firm* OR Enterprise* OR 'Private Sector' OR Industr* OR SME* OR Compan*
Relationship	Link* OR Relation* OR Cooperat* OR Collaborat* OR External OR Partner* OR Alliance
Activity	Innovat* OR R&D OR research OR transfer* OR support OR consultan*
Impact	Effect* OR impact* OR assess* OR evaluat*
Search String 1: NOV 26th, 2019 Web of Science: **14.344** Results Scopus: **2.547** Results	TOPIC: (Effect* OR impact* OR assess* OR evaluat*) *AND* TOPIC: (Firm* OR Enterprise* OR 'Private Sector' OR Industr* OR SME* OR Compan*) *AND* TOPIC: (Link* OR Relation* OR Cooperat* OR Collaborat* OR External OR Partner* OR Alliance) *AND* TOPIC: (Innovat* OR R&D OR research OR transfer* OR support OR consultan*) *AND* TOPIC: (Universit* OR HEI* OR Higher Education OR Academ*) *Index=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC TIME PERIOD=ALL YEARS*
Search String 2: NOV 26th, 2019 Web of Science: **6.585** Results Scopus: **1.584** Results	TOPIC: (Effect* OR impact* OR assess* OR evaluat*) *AND* TOPIC: (Firm* OR Enterprise* OR 'Private Sector' OR Industr* OR SME* OR Compan*) *AND* TOPIC: (Link* OR Relation* OR Cooperat* OR Collaborat* OR External OR Partner* OR Alliance) *AND* TOPIC: (Innovat* OR R&D OR research OR transfer* OR support OR consultan*) *AND* TOPIC: (Universit* OR HEI* OR Higher Education OR Academ*) Refined by: WEB OF SCIENCE INDEX: (WOS.SSCI OR WOS.SCI) AND TYPE OF DOCUMENTS: (ARTICLE) AND LANGUAGE: (ENGLISH) *INDEX=SCI-EXPANDED, SSCI. TIME PERIOD=ALL YEARS*
Search String 3 NOV 26th, 2019 Web of Science: **5.214** Results Scopus: **1.327** Results	TOPIC: (Effect* OR impact* OR assess* OR evaluat*) *AND* TOPIC: (Firm* OR Enterprise* OR Private Sector OR Industr* OR SME* OR Compan*) *AND* TOPIC: (Link* OR Relation* OR Cooperat* OR Collaborat* OR External OR Partner* OR Alliance) *AND* TOPIC: (Innovat* OR R&D OR research OR transfer* OR support OR consultan*) *AND* TOPIC: (Universit* OR HEI* OR Higher Education OR Academ*) Refined by: LANGUAGE: (ENGLISH) AND TYPE OF DOCUMENTS: (ARTICLE) AND (32 Sub Area) *INDEX=SCI-EXPANDED, SSCI. TIME PERIOD=ALL YEARS*

Table 2.B. List of Search String subareas

Agriculture;
Automation & Control Systems;
Biotechnology & Applied Microbiology;
Business & Economics; Chemistry;
Communication; Computer Science;
Construction & Building Technology;
Demography;
Education & Educational Research;
Energy & Fuels;
Engineering;
Environmental Sciences & Ecology;
Fisheries;
Food Science & Technology;
Government & Law;
Information Science & Library Science;
International Relations; Instruments & Instrumentation;
Materials Science;
Medical Laboratory Technology;
Nuclear Science & Technology;
Operations Research & Management Science;
Physics;
Public Administration;
Science & Technology – Other Topics;
Social Issues or Geography;
Social Sciences – Other Topics;
Sociology;
Sport Sciences;
Telecommunications;
Urban Studies.

Table 2.C. Articles analysed

Study	Dependent Var.	Coeff. (S. E.)	Period	Sample	Relation	Research Partner	Region
Adams et al. (2003)	Patents	**0.48 (0.253)**	1996-1998	274	Service	Res. Institute	USA
Albahari et al. (2017)	Innovative Sales Patents	-0.315 (0.241) 0.014 (0.293)	2007-2009	849	Partnership	Higher Educ. Inst.	Spain
Almeida et al. (2011)	Patents	0.019 (0.038)	1990-2003	149	Partnership	Higher Educ. Inst.	USA & EU
Arranz & Fdez. de Arroyabe (2008)	Patents Innovative Sales	**0.185 (0.000)** 0.003 (0.164)	1997-1998	4,763	Partnership	Higher Educ. Inst.	Spain
Arvanitis & Woerter (2009)	Patents Innovative Sales	**0.422 (0.183)** **0.275 (0.146)**	2001	2,428	Service	Higher Educ. Inst.	Switzerland
Arvanitis et al. (2008)	Patents	-0.154 (0.481) -0.991 (0.664)	2001	241	Service	Higher Educ. Inst. Res. Institute	Switzerland
Aschhoff & Schmidt (2008)	Productivity Innovative Sales	0.064 (0.292) **8.460 (3.490)**	2001-2004	699	Partnership	Res. Tech. Org.	Germany
Barge-Gil (2010)	Innovative Product Innovative Process	0.347 (0.322) -0.002 (0.036)	2004	3,549	Partnership	Res. Tech. Org.	Spain
Barge-Gil & Modrego (2011)	Tech. Performance Econ. Performance	-0.293 (0.292) **0.072 (0.039)**	2003-2005	257	Partnership	Res. Tech. Org.	Spain
Becker & Dietz (2004)	Innovative Product	**0.544 (0.209)**	1990-1993	2,048	Partnership	Res. Tech. Org.	Germany
Beise & Stahl (1999)	Innovative Sales	**-0.471 (0.195)** -0.482 (0.370)	1993-1996	9,782	Partnership	Higher Educ. Inst. Res. Institute	Germany
Belderbos et al. (2004)	Added Value	**0.507 (0.200)**	1996-1998	1,360	Partnership	Res. Tech. Org.	Netherlands
Belderbos et al. (2006)	Productivity	0.016 (0.061)	1996-1998	1,992	Partnership	Res. Tech. Org.	Netherlands
Belderbos et al. (2015)	Innovative Sales	0.053 (0.045)	2004-2011	9,782	Partnership	Res. Tech. Org.	Spain
Biedenbach et al. (2018)	Innovative Product	**1.530 (0.150)**	2010-2013	1,532	Partnership	Higher Educ. Inst.	Sweden
Brouwer & Kleinknecht (1996)	Innovative Product Innovative Sales	**0.820 (0.090)** 2.080 (1.825)	1990-1992	3,784	Service Partnership	Res. Institute Res. Tech. Org.	EU
Cardamone et al. (2018)	Innovative Sales Innovative Sales	**0.010 (0.006)** **0.006 (0.003)**	2004-2006	3,719	Partnership Partnership	Higher Educ. Inst.	Italy
Chen et al. (2016)	Innovative Sales	**0.146 (0.047)**	2006-2013	478	Partnership	Res. Tech. Org.	China
Darby et al. (2004)	Patents Patents	**31.973 (11.208)** **30.554 (11.254)**	1988-1996	350	Service	Higher Educ. Inst.	USA
De Marchi (2012)	Innovative Product	**0.244 (0.091)**	2007-2007	6,047	Partnership	Res. Tech. Org.	Spain
Di Maria et al. (2019)	Patents	**0.89 (0.404)**	2008-2012	350	Service	Higher Educ. Inst.	Italy
Ehrenberger et al. (2015)	Patents	**-0.140 (0.069)**	2011	1,144	Partnership	Higher Educ. Inst.	Czech Rep.
Fabrizio (2009)	Patents	**0.216 (0.112)**	1976-1999	83	Partnership	Higher Educ. Inst.	USA
Fernandes & Ferreira (2013)	Innovative Product Innovative Process	**0.400 (0.034)** **3.830 (0.224)**	2012	500	Partnership	Higher Educ. Inst.	EU
Fey & Birkinshaw (2005)	Innovative Product	0.060 (0.110)	2003	107	Partnership	Higher Educ. Inst.	UK & Sweden
Frenz & Ietto-Gillies (2009)	Sales	0.419 (1.420)	1997-2002	786	Partnership	Higher Educ. Inst.	EU

Fu & Li (2016)	Sales Innovative Product	2.111 (1.414) 3.967 (2.786)	2005-2007	1,408	Partnership	Higher Educ. Inst.	China
González-Pernía et al. (2015)	Innovative Product Innovative Process	0.025 (0.091) **0.317 (0.058)**	2003-2011	4,257 4,969	Partnership	Higher Educ. Inst.	Spain
Hall et al. (2003)	Patents	0.020 (0.340)	2004-2006	313	Service	Higher Educ. Inst.	USA
Harris et al. (2013)	Added Value	**0.151 (0.055)**	2004-2006	7,580	Partnership	Higher Educ. Inst.	UK
Hewitt-Dundas et al. (2019)	Innovative Product	**0.280 (0.060)**	2004-2014	7,580	Partnership	Higher Educ. Inst.	UK
Hou et al. (2019)	Innovative Product	**0.363 (0.088)**	2009-2014	180	Service	Res. Institute	China
Howells et al. (2012)	Innovative Product Innovative Process Innovative Sales	**2.900 (1.270)** **2.900 (1.190)** **1.500 (0.640)**	2008-2009	371	Partnership	Higher Educ. Inst.	UK
Huang & Yu (2011)	Patents	**0.413 (0.199)**	1996-2005	165	Partnership	Res. Institute	China
Inauen & Schenker-Wicki (2011)	Innovative Product Innovative Process Innovative Sales	**0.109 (0.050)** **0.118 (0.048)** **0.022 (0.012)**	2006-2008	141	Partnership	Higher Educ. Inst.	Germany, Switzerland & Austria
Kanama & Nishikawa (2017)	Innovative Product Innovative Sales	**0.900 (0.274)** **-0.927 (0.209)**	2006-2008	1,001	Partnership	Higher Educ. Inst.	Japan
Kim (2012)	Innovative Product	0.052 (0.241)	2003-2011	265	Partnership	Res. Tech. Org.	USA
Kobarg et al. (2018)	Innovative Sales	**1.060 (0.210)**	2003-2011	2,061	Partnership	Res. Tech. Org.	Germany
Medda et al. (2004)	Productivity Productivity	-0.066 (1.119) **0.542 (0.289)**	1998	2,222	Partnership	Higher Educ. Inst. Res. Institute	Italy
Neyens et al. (2010)	Innovative Sales	0.040 (0.110)	2001-2002	217	Partnership	Res. Tech. Org.	Germany
Nieto & Santamaría (2010)	Innovative Product Innovative Process	**0.722 (0.129)** **0.208 (0.084)**	1998-2002	1,300	Partnership	Res. Tech. Org.	Spain
Nuñez-Sánchez et al. (2012)	Patents Innovative Product	-0.192 (0.245) 0.098 (0.184)	1989-1995	262	Partnership	Res. Tech. Org.	Spain
Radicic & Pinto (2019)	Innovative Product Innovative Product Innovative Product	**0.132 (0.057)** **0.221 (0.100)** **0.195 (0.100)**	2001-2011 1998-2000	11,141 3,241 4,931	Partnership	Res. Tech. Org.	Spain
Robin & Schubert (2013)	Innovative Product Innovative Process	**0.240 (0.120)** -0.030 (0.020)	2002-2004	5,200	Partnership	Res. Tech. Org.	Germany & France
Tsai & Hsieh (2009)	Innovative Sales	**-0.105 (0.024)**	2005-2005	1,346	Partnership	Res. Tech. Org.	China
Turkina et al. (2019)	Patents	**0.195 (0.100)**	2000-2009	5,780	Partnership	Res. Tech. Org.	EU
Un et al. (2010)	Innovative Product	**0.410 (0.159)**	2000-2009	781	Partnership	Higher Educ. Inst.	Spain
Vega-Jurado et al. (2009)	Innovative Process Innovative Product	0.510 (0.530) 0.520 (0.470)	2002-2004	4,445	Partnership	Res. Tech. Org.	Spain
Wang et al. (2013)	Patents	**0.673 (0.380)**	2000-2005	100	Partnership	Higher Educ. Inst.	China
Yaşar & Paul (2012)	Innovative Product Innovative Process Patents	**0.686 (0.203)** 0.206 (0.210) 0.350 (0.238)	2000-2002	1,566	Partnership	Higher Educ. Inst.	China
Yu & Lee (2017)	Patents	**0.242 (0.140)**	2013	601	Partnership	Res. Tech. Org.	South Korea

Note: Coefficients and Standard Error in bold implies a statistically significant.

TABLE 4.A. Correlation Matrix

	EI	STI	Supplier	Customer	Competitors	Size	Age	Export	R&D	Subsidies	Region	Manuf. H	Manuf. M-H	Service H-T
Eco-Innovation	1.000													
STI	0.317	1.000												
Supplier	0.250	0.474	1.000											
Customer	0.240	0.503	0.477	1.000										
Competitors	0.174	0.424	0.340	0.402	1.000									
Firm size (log)	0.113	0.096	0.170	0.065	0.086	1.000								
Firm age (log)	0.029	-0.002	0.034	0.004	-0.002	0.126	1.000							
Export (%)	0.171	0.111	0.087	0.093	0.037	0.075	0.082	1.000						
R&D expenditure (log)	0.510	0.440	0.337	0.323	0.268	0.176	-0.015	0.242	1.000					
Subsidies	0.246	0.436	0.251	0.331	0.297	0.048	-0.058	0.096	0.443	1.000				
Innovative Region	0.268	0.240	0.178	0.209	0.170	0.061	0.007	0.190	0.561	0.285	1.000			
Manufacturing high technology	0.076	0.065	0.039	0.047	0.041	-0.014	0.003	0.097	0.147	0.061	0.159	1.000		
Manufacturing medium-high technology	0.134	0.009	0.014	0.023	-0.044	-0.069	0.045	0.259	0.133	0.011	0.114	-0,117	1.000	
Service high technology	0.020	0.117	0.059	0.135	0.118	-0.068	-0.067	-0.054	0.120	0.184	0.068	-0,047	-0,123	1.000

PUBLICATIONS & CONFERENCES

CHAPTER 2: Bridging the gap between innovation ecosystems and innovation systems: a bibliometric review

- Title: Bridging the gap between innovation ecosystems and innovation systems: a bibliometric review
- Coauthor: José-Ángel Miguel Dávila
- Conferences: 31st Spanish Academy of Management International Conference in Barcelona (2022)
- Journal: Submitted to Scientometrics

CHAPTER 3: "the impact of university –industry relationships on firms' performance: a meta-regression analysis"

- Title: The impact of university –industry relationships on firms' performance: a meta-regression analysis
- Coauthors: José-Ángel Miguel Dávila & Mariano Nieto
- Publication year: 2021
- Journal: *Science and Public Policy, 48(2), 276–293. https://doi.org/10.1093/scipol/scab025*
    - *JCR impact factor (2021):2,087, Management (Q4: 195/226), Public Administration (Q3: 36/49), Environmental Studies (Q4: 102/127)*
    - *AJG (2021): 2*

CHAPTER 4: "External stakeholder engagement: Complementary and substitutive effects on firms' eco-innovation"

- Title: External stakeholder engagement: Complementary and substitutive effects on firms' eco-innovation
- Coauthors: José-Ángel Miguel Dávila & Mariano Nieto
- Publication year: 2021
- Journal: *Business Strategy and the Environment, 30(5), 2671– 2687. https://doi.org/10.1002/bse.2770*
    - *JCR impact factor (2021): 10,801; Management (Q1: 16/226), Business (Q1: 19/154), Environmental Studies (Q1: 7/127)*
    - *AJG (2021): 3*