

The effects of alliance diversity and geographical distance on innovative outcomes within R&D Consortia

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Executive summary

Centrally to this research are collaborative research and development (R&D) activities between science and industry, from a consortium- and project level perspective. Within collaborative R&D activities between science and industry, multiple organisations pool resources for carrying out R&D activities. Multiple industrial organisations can be involved within these R&D Consortia, of which the composition is referred to as alliance diversity. The objective of this research is to optimise these consortia toward the achievement of innovative outcomes. The study of alliance diversity theorises an improvement of innovative outcomes through knowledge complementarity. The exchanging of knowledge is theorised to happen more efficiently when geographical distance is smaller. Alliance diversity and the geographical distance between industrial organisations are then considered as the central levers for influencing the innovative outcomes of R&D Consortia. The question central to this research is: “*To what extent does alliance diversity influence the innovative outcomes of R&D consortia, and to what extent is this relationship moderated by the geographical distance between industrial organisations?*”

The three hypotheses central to this study are:

- H1: *Within R&D Consortia, the alliance diversity of industrial organisations has an inverse U-shape relationship with innovative outcomes.*
- H2: *The geographical distance of industrial organisations within R&D Consortia has a negative linear relationship with innovative outcomes.*
- H3: *The geographical distance of industrial alliances within R&D moderates the effect of alliance diversity on innovative outcomes.*

To test these hypotheses, this research employs a quantitative explanatory research design. It is based on secondary data gained from the Netherlands Organization for Scientific Research (NWO) and considers R&D Consortia within a subdomain of the NWO, which is the Applied and Technical Sciences (TTW) domain. Multiple Ordinal Logistic Regressions have been used for predicting the innovative outcomes of these consortia and then determining the influence of alliance diversity and the geographical distance of industrial organisations.

The results did not provide significant evidence to accept the first hypothesis. Indicators have been found towards the influence of alliance diversity on the knowledge generation within R&D Consortia. The observed relationship showed an inverted U-shape, even though this relationship was moderately significant. It is an indicator that an optimum exists for the alliance diversity within R&D Consortia. Managers of R&D Consortia should aim for the inclusion of slight alliance diversity for optimising the generated knowledge. Pure heterogeneity or homogeneity of alliance diversity should be avoided for optimising knowledge generation. An effect for alliance diversity on the economic- and societal gains generated through R&D Consortia has not been identified. The geographical distance between industrial organisations has not been found as a significant predictor for the innovative outcomes of R&D Consortia, so the second hypothesis cannot be accepted. The predictive models for the third hypothesis were subject to multicollinearity, so no reliable statements can be made about this. Through additional exploratory analysis, indicators for the existence of funding as a moderating variable between alliance diversity and the generation of new knowledge has been found. It is theorised that funding provides access to additional resources which enables the materialization of the additional knowledge gained through alliance diversification.

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1. Introduction

1.1. R&D Consortia

Centrally to this research are collaborative research and development (R&D) activities between science and industry, from a consortium- and project level perspective. Within collaborative R&D activities between science and industry, multiple organisations pool resources for carrying out R&D activities. When these arrangements are considered on an organisational level, they are referred to as R&D Consortia (Rubin, 1991; Smit, 2018). Within available literature, collaborative arrangements which exclusively observe the scientific and industrial aspects are specified as science-industry collaborations (Cantner et al., 2024). Within the study of science-industry collaborations, the project level is highlighted to be of importance (Albats et al., 2018). The project level refers to the stakeholders and actors involved in carrying out the R&D activities. Successful outcomes of projects provide economic and intellectual benefits for firms and their employees (Cobo-Benita et al., 2016; Balachandra & Friar, 1997; Dvir et al., 1998; Ika et al., 2012; Pinto & Mantel, 1990; Scott-Young & Samson, 2008). The project level is relevant for scholarly-, practical- and policy-related advancements. Knowledge on the project level can provide guidance to those involved in the structuring and managing of projects, and contribute to decisions on resource allocations (Cantner et al., 2024; Flores et al., 2009). Even though the project level is deemed to be of importance, a substantial gap is reported within the literature (Cantner et al., 2024; Flores et al., 2009; Perkmann et al., 2021).

1.2. Importance of collaboration

Science-industry collaborations allow for joint knowledge generation which can be used for solving technical problems and generating innovations. This subsequently leads to increased economic growth and welfare (de Wit-de Vries et al., 2019; Kaufmann & Tödtling, 2001; Roncancio-Marin et al., 2022). There is an increasing tendency for science and industry to collaborate for a multitude of reasons, one of which is an increase in scientific productivity (Kaufmann & Tödtling, 2001; Perkmann et al., 2013, 2021). Scientists can accomplish their objective of engaging with the surrounding economic- and innovation ecosystems through collaborating with industry (Cunningham & Link, 2015; Laredo, 2007; Shore & McLauchlan, 2012). Science-industry collaborations contribute to the exchange and transfer of knowledge between academia and industry, and lead to the co-creation of new knowledge (Compagnucci & Spigarelli, 2020; De Silva et al., 2023; Sánchez-Barrioluengo et al., 2019; Schulte, 2004).

1.3. Financial pressure, efficiency & outcomes

Key reasons for scientists and industry to collaborate include the acquisition of additional (financial) resources (Audretsch et al., 2010; Cantner et al., 2024; Celeste et al., 2014; Lam, 2011). As of lately, scholars have become concerned with increasing financial pressure on scientific research. Various factors such as geopolitical tensions, national budget changes and changing values provide explainability for the increasing financial pressure (Geneva Rights and Climate Talks, 2025; Jeremias, 2025; Mann & Hotez, 2025a, 2025b; Royal Society, 2025; Tian et al., 2025; Universities UK, 2025; World Federation of Public Health Associations, 2025). The increasing constraints on financial resources for scientific research arise due to a multitude of reasons, ranging from societal challenges, to global- or national economic and policy related changes. As the illustrated problem is so multifaceted, this research will not directly approach the increasing financial constraints for scientific research globally. Instead, this research will approach the increasing constraints on financial resources by considering options for improving efficiency.

Within literature on science-industry collaborations and R&D Consortia, innovative outcomes are frequently studied (Alegre et al., 2025; Baron et al., 2014; Chen et al., 2019; Eisner et al., 2009; Mannak et al., 2023; Mothe & Quelin, 2001). The resource-based view within strategic management highlights firm resources as a fundamental component for competitive advantage (Barney, 1991; Capaldo & Petruzzelli, 2014; Peteraf, 1993). The knowledge-based view of firms highlights knowledge as the most important strategic resource, as it is the primary input for innovation, which can be used for adapting to increasingly evolving environments (Capaldo & Petruzzelli, 2014; Grant, 1996; Rothaermel & Deeds, 2004). Industry has access to basic knowledge and co-creation of new knowledge through collaborating with scientific institutions, which then contributes to their economic activities by increasing innovative output (Perkmann et al., 2011).

1.4. Alliance diversity & geographical distance

Within R&D Consortia, multiple companies can be involved, forming an alliance of industrial organisations (Brunetta et al., 2020; Chen et al., 2019; Doz et al., 2000; Leeuw et al., 2012). An alliance which involves multiple companies is referred to as a multi-partner alliance. Within the context of a R&D oriented multi-partner alliance, the composition of the involved industrial organisations is known as alliance diversity (Leeuw et al., 2014; Terjesen et al., 2011; Xu & Zeng, 2021). Within the study of new product development, alliance diversity is theorised and observed to affect the delivered innovative output through knowledge complementarity (Duysters & Lokshin, 2011; Xu & Zeng, 2021). The knowledge provided by multiple companies within an alliance, influences the innovative outcomes of firms. During the formation of multi-partner alliances, an optimum composition of shared knowledge between industrial organisations can be achieved. This allows for an optimization for achieving innovative outcomes by increasing the efficiency of used financial resources. Within R&D Consortia, an alliance of industrial organisations is also formed. The effects of alliance diversity on innovative outcomes within R&D Consortia has yet to be observed.

Alliance diversity is mainly theorised to provide benefits through knowledge complementarity. For the benefits of knowledge complementarity to materialize, the additional knowledge has to be exchanged between involved parties. Measuring the exchange of knowledge can be difficult, because many nuances need to be accounted for (Feldman & Kogler, 2010). Higher geographical distance is theorised to increase the costs of knowledge exchange (Forman & van Zeebroeck, 2019). Closer geographical distance is observed to contribute to higher levels of innovation than distant geographical alliances within industrial R&D collaborations (Santamaría et al., 2021). Within scientific research, closer geographical distance is observed to improve the quality of R&D collaborations (Pialli, 2023). Within R&D Consortia, multiple organisations collaborate to exchange knowledge with the aim of carrying out R&D activities. Greater geographical distance is associated with higher costs for facilitating knowledge exchange. Closer geographical distance is theorised to improve knowledge exchange and subsequently improve innovative outcomes. Alliance diversity is theorised to improve innovative outcomes through knowledge complementarity. It is unknown if closer geographical distance of the industrial alliance within R&D Consortia improves the innovative outcomes.

1.5. Research question

Within this research, the objective is to find opportunities to improve the efficiency of R&D Consortia for achieving innovative outcomes. In other R&D contexts, the alliance diversity of industrial organisations and their geographical distance is theorised and observed to affect innovative outcomes. In R&D Consortia, this effect has yet to be observed. The lack of available literature is theorised to exist due to the inherent complexity of such projects (Albats et al., 2018; Perkmann et al., 2021). Creating a deeper understanding of the input for innovation of R&D Consortia, will enable optimization without necessarily requiring additional financial resources. These observations lead to the following research questions:

- 1. “To what extent does alliance diversity influence the innovative outcomes of R&D consortia?”*
- 2. “To what extent is the relationship between alliance diversity and innovative outcomes within R&D consortia moderated by the geographical distance between industrial organisations?”*

Forming an answer towards the research questions would provide governors of R&D Consortia with more comprehensive knowledge towards achieving innovative outcomes. Answers to these research questions could potentially have provide widespread benefits, spreading beyond academia (Leydesdorff & Etzkowitz, 1998, 2000). At its core, an answer towards the research questions would contribute to the protection of scientific research under increasing financial constraints.

2. Theoretical framework and hypothesis

2.1. Definition of R&D Consortia

R&D Consortia are temporary collaborative agreements in which scientific institutions and industrial organisations pool resources for carrying out R&D activities. R&D Consortia specifically refer to the observation of these collaborative arrangements on an organisational level. R&D Consortia have been chosen as the centrally studied concept, because these type of arrangements include scientific institutions and the pooling of (financial) resources, which has been identified as a potential pressure point for science. Additionally, the study of science-industry collaborations brings the project level to the forefront. The project level refers to the people involved in carrying out the R&D activities. This is deemed to be of importance as the success of the performed R&D activities depends upon the people which perform them. This research will study collaborations between science and industry from a consortium and project level perspective. This means that the collaborative arrangements will be studied on an organisational level and include an integration of the people which perform the R&D activities.

2.2. Definition of innovative outcomes

The definition of innovative outcomes tends to change according to the context of which it is applied. Within this research, the innovative outcomes of R&D Consortia are defined as the newly generated knowledge, the (potential for) economic gains, and the benefits to society. Innovative outcomes are time-sensitive, as they need time to mature. The definition has been constructed by studying and aligning the perspectives on innovative outcomes of multiple stakeholders involved in R&D Consortia. Additionally, the innovative outcomes from a project level have been included as well. Common innovative outcomes from a scientific perspective include newly generated knowledge, potential for economic gains and the societal benefits (Arza, 2010; Cantner et al., 2024; Grimaldi & Von Tunzelmann, 2002). The innovative outcomes considered by scientific institutions and scientists are associated with each other (De Fuentes & Dutrénit, 2012). Innovative outcomes from an industrial point of view also include newly generated knowledge, economic gains and societal benefits (George A. Giannopoulos & John F. Munro, 2019). The study of innovative outcomes on a project level highlights the time sensitivity nature of innovations (Albats et al., 2018; Ankrah et al., 2013; Arza, 2010; Cantner et al., 2024; D'Aspremont & Jacquemin, 1988; Nikulainen, 2010; Perkmann et al., 2011).

2.3. Knowledge as a mechanism

The type of resources that are pooled within R&D Consortia can be tangible or intangible (Mothe & Quelin, 2001). Tangible resources generally reflect physical assets, such as the financial resources. Intangible resources are non-physical assets, which are harder to imitate and substitute (Barney, 1991; Dierickx & Cool, 1989; Peteraf, 1993; Schriber & Löwstedt, 2015). For example, one of the intangible resources is knowledge. Within an R&D Consortia, knowledge is provided by the industrial organisations. The theory of the Knowledge Based View (KBV), provides insights into the application of knowledge for industrial organisations. The KBV states that knowledge is the primary input for innovation of individual industrial organisations (Capaldo & Petruzzelli, 2014; Grant, 1996; Rothaermel & Deeds, 2004). The knowledge of individual industrial organisations is not limited to their own, as they can collaborate with other industrial organisations (Collins & Riley, 2013; Leeuw et al., 2014; Sampson, 2003). Thus, knowledge enables firms to innovate, and they can access additional knowledge through collaboration with other firms.

2.4. Alliance diversity

The composition of industrial organisations within a multi-partner R&D alliance is known as alliance diversity (Collins & Riley, 2013; Leeuw et al., 2012, 2014; Sampson, 2003; Terjesen et al., 2011). Alliance diversity and the effects on innovative outcomes have readily been studied within the context of industrial organisations, defined as Alliance Portfolio Diversity (APD). This theory has yet to be incorporated within the broader setting of R&D Consortia and its innovative output. Even though the theory of APD has yet to be placed within the context of R&D Consortia, indicators for the existence of such an effect exists. The innovative output of multi-partner R&D alliances aligns with the theorised innovative output of R&D Consortia. As a part of R&D Consortia are multi-partner R&D alliances, it does seem likely that the same effect as observed in APD extends to broader collaborations which include scientific institutions.

Within the study of alliance diversity, low diversity is associated with little variation in the knowledge of the involved firms. These lower levels of diversity are then associated with worse innovative performance. The APD theory indicates that increasing diversity brings increasing levels of knowledge. Such an increase in available knowledge within an R&D alliance is then related with increasing levels of innovative performance. These benefits of increasing innovative performance increase up until a certain point, after which it will start to decline. When alliance diversity levels are moderate, there is a moderate availability of diversity in knowledge. Through the complementarity of different knowledge bases, these firms can improve their innovativeness. However, when alliance diversity keeps increasing, the diversity in knowledge also increases. When alliance diversity becomes too high, increased difficulty in exchanging knowledge starts to cause a decline in innovative performance.

High levels of alliance diversity are associated with high levels of diversity in knowledge. As the diversity of knowledge increases, so does the difficulty of exchanging that knowledge. Increases in the difficulty of exchanging knowledge make it more difficult to apply that knowledge towards the generation of innovations. When alliance diversity levels are low, there is little variation in available knowledge, so the innovative outcomes are relatively low as well. When the alliance diversity increases, so does the available knowledge, which enables an increase in innovative performance. Increasing available knowledge indefinitely does not increase innovative performance indefinitely, as this is associated with an increase in the difficulty for exchanging knowledge. Increases in innovative performance caused by increasing alliances diversity continues up until an optimum, after which it will start to decrease.

When the relationship between alliance diversity and innovative performance within multi-partner alliances are graphed, an inverse U-shape becomes visible (Collins & Riley, 2013; Leeuw et al., 2012, 2014; Sampson, 2003). These observations have just been made within multi-partner R&D alliances, and not within the context of R&D Consortia. As multi-partner R&D alliances share characteristics with R&D Consortia in terms of the innovative output, the first hypothesis will look for a similar relationship. The first hypothesis aims to understand if an inverse U-shape relationship between alliance diversity and innovative outcomes within R&D Consortia is present. The first hypothesis has been formed as:

H1: Within R&D Consortia, the alliance diversity of industrial organisations has an inverse U-shape relationship with innovative outcomes

2.5. Geographical distance between industrial organisations

The association that alliance diversity influences the innovative output of R&D Consortia, is based upon the theory that diverse knowledge leads to improved innovative performance. An essential component for benefits gained through the additional knowledge to materialize, is that this knowledge is exchanged between actors. The exchanging of knowledge is dependent upon which type of knowledge is being exchanged. Some knowledge is easily documentable and so easily transferable over distance. Other knowledge, known as tacit knowledge, is hard to document and ingrained within individuals or groups. During collaborations, tacit knowledge can be exchanged through observation, interaction or imitation (van der Wouden & Youn, 2023). Current literature on the knowledge exchange within collaborations show that the exchange of knowledge happens more efficiently when the geographical distance between two separate parties is smaller (van der Wouden & Youn, 2023; Vlajcic et al., 2018). Concurrently, this effect has also been observed in knowledge exchange between scientific institutions (Ponds et al., 2007). Moreover, research which has studied the geographical distance between different organisations within multi-partner alliance have observed similar effects (Leeuw et al., 2014; Meyer-Krahmer & Reger, 1999; Piali, 2023; Santamaría et al., 2021; Terjesen et al., 2011).

An increase in geographical distance is associated with increasing difficulty in the exchanging of knowledge. As knowledge is the primary input for innovation, the increasing difficulty in the exchanging of knowledge is theorised to result in a decrease in innovative performance. This effect has been observed between the industrial organisations involved in multi-partner R&D alliances (Leeuw et al., 2014; Meyer-Krahmer & Reger, 1999; Piali, 2023; Santamaría et al., 2021; Terjesen et al., 2011). Increasing geographical distance between industrial organisations is associated with decreasing innovative performance. The relationship between geographical distance of industrial organisations and the innovative output of R&D Consortia would then be negative and linear. These observations lead to the second hypothesis:

H2: The geographical distance of industrial organisations within R&D Consortia has a negative linear relationship with innovative outcomes

As highlighted in the previous chapter, the benefits of alliance diversity are mainly theorised to exist due to the exchange of additional knowledge between industrial organisations. Within the available literature on the exchanging of knowledge, it is shown that the geographical distance between separate organisations is of importance. It has been observed that the exchanging of knowledge happens more efficiently when separate parties are in closer proximity. Through a connection of the theory on the exchange of knowledge to that of alliance diversity, the third hypothesis is formed. Alliance diversity is theorised to provide benefits through knowledge exchange, and knowledge exchange is theorised to happen more efficiently when separate parties are within closer geographical distance. When these two are connected, then it would seem that the geographical distance between the involved parties within an R&D Consortia, moderates the potential benefits of alliance diversity on innovative outcomes. A combination of these theories then leads to the third hypothesis.

H3: The geographical distance of industrial alliances within R&D moderates the effect of alliance diversity on innovative outcomes

In summary, the first hypothesis theorises an inverse U-shape relationship between alliance diversity and the innovative outcomes of R&D Consortia. The second hypothesis theorises to find a negative and linear relationship between the geographical distance of industrial organisations and the innovative outcomes. The final hypothesis theorises a moderating effect by the geographical distance of industrial organisations between alliance diversity and the innovative outcomes of R&D Consortia. For an overview of these three separate hypotheses, see *Figure 1: Theoretical Model*.

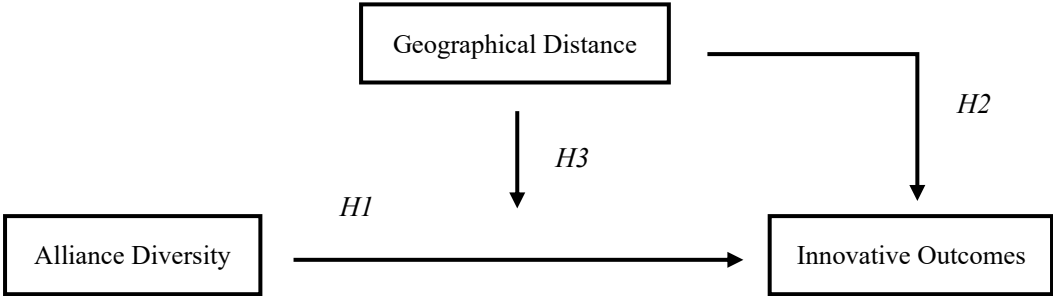


Figure 1: Theoretical Model

In the first arrow marked by *H1*, low alliance diversity relates to low innovative outcomes. An increase in alliance diversity initially leads to an increase in innovative outcomes. After some, yet to be identified point, increases in alliance diversity will lead to lower innovative outcomes. In the second arrow marked by *H2*, the effect of geographical distance between industrial organisations on the innovative outcomes of R&D Consortia is marked. Lower geographical distance between industrial organisations is expected to improve the innovative outcomes of R&D Consortia. Finally, alliance diversity is theorised to improve innovative outcomes through the exchanging of complimentary knowledge, and geographical distance is theorised to improve the exchanging of knowledge. These two theories are then combined, and the moderating effect of geographical distance between industrial organisations on the effects of alliance diversity on innovative outcomes is studied. This final hypothesis is highlighted by the third arrow, *H3*.

3. Method

3.1. Data source

This research employs a quantitative explanatory research design to determine the influence of alliance diversity and geographical distance of alliance partners on the innovative outcomes within R&D Consortia. This study is based on secondary data gained from the Netherlands Organization for Scientific Research (NWO). The NWO is a governmental funding agency for scientific research. The main objective of the NWO is improving the quality and innovative output of scientific research happening within their domain (*NWO | Organisatie*, z.d.). This research considers R&D Consortia within a subdomain of the NWO, which is the Applied and Technical Sciences (TTW) domain. Within the R&D Consortia of the NWO, the R&D activities are mainly carried out by the involved scientists. Several processes of NWO have been standardised, such as within the acquisition of funding, the procedure towards achieving scientific and societal impacts (*NWO | Kennisbenutting*, z.d.; *NWO | Financiering*, z.d.).

The main body of the data has been constructed by combining two separate data sources from the NWO. The first body of the data has been formed by two annual reports from within the TTW subdomain. Within the annual reports, data on the innovative outcomes, the involved industrial organisations from a consortium level, and their geographical locations is provided. Information on a project level is not available within these annual reports. To attain this data, all information on researchers responsible for carrying out the R&D activities, has been gathered through a public database (*NWOpen-API*, 2025). The final observation of an important aspect of innovative outcomes from a project level, is the time sensitivity of the innovations. The innovative outcomes within the annual reports have initially been constructed by the TTW at the ending of the projects. Then, after 5 years, the projects were revisited and the innovative outcomes were rated again. These ratings have been constructed by the TTW, so they are objective and independent of the people and organisations involved within the R&D Consortia.

3.2. Sample selection

The data has been sampled from TTW projects within the years 2016 and 2017. As mentioned previously, the main body of the data consists of two separate data sources. Information from both of these sources was necessary for acquiring the required data. The selection of these years has come from the moments in which the two separate data sources overlapped. At the time of the gathering of the data, the final annual report available was that of 2023, with earlier reports dating all the way back to 2012. The innovative outcomes of the projects have been revisited 5 years after the ending of the projects, which meant that the final report from 2023 included data on projects that ended in 2017. This data then had to be enriched through the other data source, which included data on the project level. When this database was accessed, data on the project level was available from the year 2016 and onwards. This then resulted of an overlap of the two separate data sources, within the years 2016 and 2017. Even though the selection of these two years has been arbitrary, the two data sources within this period provide access to the necessary data for approaching the research questions. While the innovative outcomes have been measured consistently by the TTW, further steps were necessary to measure the alliance diversity and geographical distance.

3.3. Operationalization of variables

3.3.1. Innovative outcomes

Within the construction of the theoretical framework, innovative outcomes within R&D Consortia have been defined as the newly generated knowledge, (potential for) economic gains, and societal benefits. Within the annual TTW reports, the innovations of the R&D Consortia are rated on two separate metrics. This would make it seem that there is some disparity between the defined and measured innovative output of R&D Consortia. However, one of the two metrics for innovative output reflects the combined (potential for) economic gains and societal benefits. The other measurement for innovative output reflects the newly generated knowledge. These two separate measurements then reflect the newly generated knowledge, (potential for) economic gains, and societal benefits. In which, the newly generated knowledge can be measured separately.

The measurements on innovative output constructed by the TTW range from 4 separate levels: 0, A, B and C. Within all of the observed projects, within both measurements for innovative output, the lowest possible rating of 0 has only been observed once. An inclusion of a single outcome which has only been observed once would not provide any valuable insights but would increase complexity of the analyses. Such an increase in complexity would then decrease the interpretability and validity of the remaining analyses. For this reason, the measurement with the lowest outcome of 0 has been omitted and will not further be discussed.

The TTW has provided a description on how the remaining three outcomes of A, B and C have been constructed. Within the description of the 'A' outcome for both metrics, it is described that no innovative outcomes have been achieved. This outcome is then treated as the lowest achievable outcome. It is not excluded that projects with an A rating can achieve innovative outcomes in the future, but this would require more research. Within the description of the innovative outcomes with a B rating, it has been described that some innovations have been achieved. With the first metric describing that some useable knowledge has been attained, which still needs refinement as it is not useable yet. The other metric describes that economic gains have been made incidentally, that (a part of) the knowledge has been sold or that the results are of benefits to society. For the final 'C' measurement of innovative outcomes, it has been described that significant gains in knowledge, economic, or societal benefits have been achieved. The newly generated knowledge is then measured through separate outcomes, which can be delivered software, a working prototype, a process description or a patent. These are all included within the single metric for newly generated knowledge. Within the second metric for the economic gains and societal benefits, a rating of C indicates that significant (financial) gains have been achieved or are likely to be achieved within the upcoming 5 years.

Even though it is clear how these metrics for innovative outcomes have been constructed, and what each measurement reflects, the true distance between these separate outcomes is unknown. The distances between A, B and C could be theorised through the descriptions given by the TTW, as a qualitative description has been given. It is however unclear if these measurements for innovative outcomes include a quantitative aspect, so knowing the true distance is not possible. For this reason, the three separate possible ratings of A, B and C, for both metrics on innovative outcomes, will be treated as ordinal. Treating the three ratings of A, B and C as ordinal, ensures that they are treated from low to high, which is a very clear characteristic seen in the descriptions. By treating them as ordinal, no fixed distances between the separate ratings are assumed. Treating the measurements for innovative outcomes as ordinal, increases the interpretability and minimizes the risk of introducing bias.

3.3.2. Alliance diversity

The alliance diversity within R&D Consortia has been defined as the composition of the involved industrial organisations. Within the theory of alliance diversity, the improvements towards innovative outcomes are theorised to come into fruition through increasing knowledge. This means that to come to an estimation of the alliance diversity within the R&D Consortia, an indication of the knowledge provided by the industrial organisations is necessary. Because knowledge is an intangible resource, it can be difficult to quantify and measure. Knowledge is a resource which can be observed from a multitude of different perspectives. An indication for knowledge on the consortium level is necessary, as alliance diversity relates to the composition of organisations. Within the theory on the Knowledge Based View, it is argued that the productive activities of a firm, reflect the organization's theoretical preoccupation (Grant, 1996). In other words, the economic activities of organisations, reflects their knowledge. The economic activities are not a definitive description of all the knowledge an organisation could possibly possess, but it is a sufficient reflection of knowledge on a consortium level. Thus, an indicator of the economic activities all industrial organisations within the R&D Consortia has been acquired. These economic activities reflect their knowledge on a consortium level, which can then be used to the estimate alliance diversity for the observed R&D Consortia.

Within the Netherlands, companies need to specify their economic activities to the Netherlands Chamber of Commerce (KVK, z.d.). Each company has to properly define their economic activities, as a false report can result in a multitude of negative consequences (Boer, 2025). The standard which is used within the Netherlands to classify the economic activities is the Standard Industrial Classifications (SBI). The SBI has been constructed by the Central Bureau of Statistics and is in use by the Dutch government for the statistical analysis of economic activities (CBS, 2025a). Thus, the SBI provides an excellent reflection of economic activities of industrial organisations within the Netherlands. However, not all industrial organisations within the constructed database are located within the Netherlands. So, a broader classification system is necessary for the identification of the economic activities for all industrial organisations. For this, the standard used for the classification of economic activities within the European Union has been used. The classification system used by the European Union is the Nomenclature of Economic Activities (NACE). The identification system used within NACE is largely identical to those within the SBI (CBS, 2025a). It is then possible to match the economic activities described through the NACE with those of the SBI. Thus, a combination of the SBI with the NACE enables the identification of the economic activities for all industrial organisations located within the European Union. For the few companies located outside of the European Union, an estimation for a matching classification has been made. This has been done by identifying the primary activities which they report, accompanied a search for any branches located within the European Union and their NACE classification. All of the identified classifications have been manually verified, for a detailed explanation of the data gathering process see [Appendix I: Data Gathering Process](#).

Now that a method has been identified for the classifying of economic activities, which reflects the organisations' knowledge on a consortium level, an estimation for alliance diversity within all R&D Consortia is needed. For this, the SBI codes of all industrial organisations within the R&D Consortia, will be converted to a numeric metric for alliance diversity. Within the SBI system, multiple digits are assigned to a descriptive of economic activities. The first two digits are aligned with the International Standard Industrial Classification of All Economic Activities (ISIC). The ISIC has been in use since 1948, and has since then been used by the majorities of countries worldwide for classifying economic activities (United Nations, 2025). These first two digits have thus included for the classification of economic activities.

The third and fourth digits of the SBI classification, are identical to those within the NACE (CBS, 2025a; Eurostat, 2025). The third and fourth digit provide greater detail on the economic activities compared to the first two digits. When the first two digits of two separate organisations are identical, their economic activities are similar. If the third and fourth digits are identical, then the economic activities of organisations are nearly identical. Thus, by integrating the first four digits, it can be estimated if companies share similar, or nearly identical economic activities. This does however require a measurement for diversity, that enables the use of two numeric values. This measurement should reflect whether the economic activities are completely different, slightly different, or nearly identical for multiple organisations within a single R&D Consortium. Ordinarily, measurements such as the Blau- or Herfindahl-Hirschman Index are frequently used for this purpose (Peter M. Blau, 1979; Rhoades, 1993). The Blau- and Herfindahl-Hirschman Index can include one numeric value, so is not suitable for measuring the alliance diversity in this instance. Thus, a different measurement has been identified which is able to meet the set requirements for measuring alliance diversity.

The identified measurement that meets the requirements is Rao's Quadratic Entropy (see *Equation 1: Rao's Quadratic Entropy for Alliance Diversity*). Rao's Quadratic Entropy is a measurement that has originated from the study on ecology, and was originally used for measuring diversity within ecological populations (Rao, 1982). Recently, this measurement has gained traction for the use of estimating diversity within other fields, such as quantitative economics (Carmichael et al., 2023). With the use of Rao's Quadratic Entropy, a measurement for alliance diversity has been created. Each industrial organisation is compared with the other industrial organisations within the same R&D Consortium. First, the first and second SBI digits are compared. If these are identical, then the third and fourth SBI digits are compared. Through this, it is determined if the economic activities are completely different, somewhat similar or nearly identical for all industrial organisations within a R&D Consortia. The proportion of each classification present within a R&D Consortium is calculated. Consequentially, similarity scores for the industrial organisations are calculated. If all SBI digits are identical, a similarity score of 0 is assigned. This indicates that there is no diversity. When the first two SBI digits are identical, but the third and fourth differ, a similarity score of 0.5 is assigned. This indicates that the two organisations are somewhat similar. When all of the SBI digits differ, a similarity score of 1 is assigned, which indicates complete dissimilarity. The calculated proportion is then multiplied with the similarity score. This is calculated for each industrial organisation within a single R&D Consortium, after which all the values are summed. This results in a final numerical value which reflects the alliance diversity within a singular R&D Consortium. The final values fall in between 0 and 0.5, which indicates low diversity and high diversity respectively.

$$Q = \sum_{i,j}^s d_{ij} p_i p_j$$

Q : Alliance diversity

p_i : Proportion of firms in category i

i, j : Organisation i and j

p_j : Proportion of firms in category j

d_{ij} : Similarity score i and j

S : n firms in R&D consortium

$$d_{ij} = \begin{cases} 0 & \text{if main category}_i = \text{main category}_j \text{ and sub category}_i = \text{sub category}_j, \\ 0.5 & \text{if main category}_i = \text{main category}_j \text{ and sub category}_i \neq \text{sub category}_j, \\ 1 & \text{if main category}_i \neq \text{main category}_j \end{cases}$$

3.3.3. Geographical distance

Furthermore, an estimation of the geographical distance between the industrial organisations within a consortium is necessary. The exchanging of knowledge is theorised to happen more efficiently, if geographical distance is closer. Within the acquired data source, the city of each industrial organisation is given. The city names could provide an indication of geographical distance, but only if the industrial organisations are located within the same city. Two cities could then be right next to each other but would then be treated as completely geographically distant. Solely the city name does not provide a comprehensive and nuanced picture on the geographical distance, so additional data is necessary. To connect the geographical distance of different cities, a broader metric which clusters different cities is necessary. Within the Netherlands, a common statistical approach for classifying regional division is done by clustering cities within the COROP regions (CBS, 2025b). Connecting the COROP region to the city names enables the approximation of geographical distance between two separate cities within the Netherlands. The specified geographical locations for the companies outside of the Netherlands include the country and city names.

Thus, it is now possible to determine if different companies within a consortia are within the same city, region or country. A measurement is necessary which reflects the geographical distance, between multiple industrial organisations, within a single consortium. There are multiple identifiers, which provide increasing details on similarity within a single population. For the industrial organisations within the Netherlands, the city name and COROP region are available. The used measurement should thus be able to incorporate if multiple industrial organisations within a R&D Consortium are within the same city or within the same region. This closely resembles the requirements for the creation of a measurement for alliance diversity. Thus, the measurement of Rao's Quadratic Entropy will also be used to determine geographical distance (see *Equation 2: Rao's Quadratic Entropy for Geographical Distance*). The same logic will be applied as in the construction of the measurement for alliance diversity. Through the application of Rao's Quadratic Entropy, a singular numeric value can be determined which resembled the geographical distance the involved industrial organisations. The formula has to be adjusted for the industrial organisations located outside of the Netherlands. These industrial organisations are nested within 23 different countries, so it is not feasible to collect all regions for each of these countries. For each company located outside of the Netherlands, the city and country names are available. With the use of these two variables, is possible to determine if these companies are within the same city, or in the same country. This is deemed to be sufficient for estimating the geographical distance of companies outside of the Netherlands.

$$Q = \sum_{i,j}^s d_{ij} p_i p_j$$

Q : Geographical distance

p_i : Proportion of firms in region i

i, j : Organisation i and j

p_j : Proportion of firms in region j

d_{ij} : Geographical similarity firm i and j

S : n firms in R&D Consortium

$$d_{ij} = \begin{cases} 0 & \text{if } \text{COROP}_i = \text{COROP}_j \text{ and } \text{City}_i = \text{City}_j, \\ 0.5 & \text{if } \text{COROP}_i = \text{COROP}_j \text{ and } \text{City}_i \neq \text{City}_j, \\ 1 & \text{if } \text{COROP}_i \neq \text{COROP}_j \end{cases}$$

Equation 2: Rao's Quadratic Entropy for Geographical Distance

3.3.4. Control variables

To ensure robustness, several control variables were identified in prior research on alliance diversity, innovative performance, science-industry collaborations and R&D Consortia. First off, it has been constituted that the involvement of companies is a major contributor for the success of R&D Projects (*Maatschappelijke impact in kaart - KNAW*, z.d.). For the alliance diversity of companies to have an influence on the project, companies need to be involved in the project. The *company involvement* is included as the first control variable. Within our dataset, a measurement is provided on the level of involvement of companies throughout a singular project. This measure is provided for each individual R&D Consortium.

The resources an R&D Consortium has access to play a crucial role in the attainable outcomes. Within available literature, the financial resources available to an R&D Consortium are illustrated to be of importance. The acquired data gives access to the financial funding for each project, which is called the project funding. The available financial resources of each R&D consortium are included as the second control variable. This variable is referred to as *project funding*.

As the number of companies involved within a singular project increase, the probability of finding increased alliance diversity most likely will increase. To be sure that this does not cause any problems, the number of involved companies need to be controlled for. The *number of companies involved* within an R&D Consortium is included as the third control variable.

Some of the companies within the available are located within the Netherlands, and some are located outside of the Netherlands. The research within the consortia is mainly carried out within the Netherlands. The construction for geographical distance does include the countries which are outside of the Netherlands. If companies are located within two completely different regions, then they are considered to be dissimilar in geographical distance. The same instance occurs if countries are not located within the Netherlands. To accentuate that companies located outside of the Netherlands differ from those located within the Netherlands, the *number of companies abroad* is included as the fourth control variable.

Current research specifying the factors and interdependencies influencing the outcomes of science-industry collaborations projects, highlights the involved scientists as important variables for the innovative outcomes of scientific research (Cantner et al., 2024). To consider differences in the size of the scientific research aspect, the *number of researchers* is included as the fifth control variable.

The observed R&D Consortia have all been conducted within the Technical and Applied Sciences domain of the NWO. This indicates that the performed research, has a technical and applied orientation. The scientific institutions responsible for carrying out the research, differ in specialization. Available literature on the innovative outcomes from research performed at industrial organisations, indicate that research with a focus on applied and technical sciences, are more likely to provide innovative outcomes (Ceccagnoli et al., 2024). The observed R&D Consortia have been carried out within a domain that has a technical orientation. To account for any potential differences which could occur due to the research institutes having a technical specialization, institutes with a *non-technical research orientation* have been controlled for.

3.4. Analytical approach

The aim of this research is to understand if alliance diversity and geographical distance influence the innovative outcomes of R&D Consortia. As has been described earlier, the data provides two separate metrics which reflect the innovative outcomes. Innovative outcomes within R&D Consortia reflect newly created knowledge, economic benefits and societal benefits. For the measurement of innovative outcomes within the observed consortia, two metrics are available. Within the first measurement of innovative outcomes, the consortia are rated on the generated knowledge, reflected through the technological readiness of the delivered products. Furthermore, a second metric is available which combines the economic- and societal benefits. Both measurements for innovative outcomes within R&D Consortia are treated as ordinal. The observed ratings range from low to high by either an A, B or C.

The theorised effect of alliance diversity on the innovative outcomes is non-linear. Furthermore, the measurements for innovative outcomes are ordinal. The objective of this research is to identify the effects of alliance diversity and geographical distance on the innovative outcomes. So, an analytical method for observing a non-linear effect of multiple independent variables on an ordinal dependent variable is necessary. An analytical methods which fits these requirements is the Ordinal Logistic Regression (OLR). An OLR can be used for predicting the outcomes of an ordinal dependent variable, based upon the included dependent variables. It is then possible to include a test for a non-linear relationship by including summation of the linear and quadratic term of the independent variable (Haans et al., 2016; Stam, 2009).

For the testing of the multiple hypotheses, distinct models should be created. Three distinct OLR models have been built, each building upon the previous one. Within the first model, only the control variables are used to predict the innovative outcomes. The second model adds the main effects of alliance diversity and geographical distance, independently. Then within the final model, the moderating effect of geographical distance on the relationship between alliance diversity and innovative outcomes is added. From these models, some unexpected results were attained, which lead to an exploratory analysis that built upon the first two models.

3.5. Validity & Reliability considerations

Within the use an OLR, a key assumption is that the effect of an independent variable, is the same for all ordinal outcomes. This is known as the Proportional Odds Assumption (Jumbong, 2025). To test for the Proportional Odds, Likelihood Ratio Tests (LRT) have been used (Kingdom & Prins, z.d.). A significant value within the LRT indicates that the effects of the independent variables, are proportionally dispersed among the ordinal outcomes.

To check for correlation between independent variables, a correlation matrix was constructed. Besides correlation between two separate independent variables, an independent variable can be correlated to a combination of multiple independent variables. This concept is known as multicollinearity. If multicollinearity is found for a variable, then implications for that variable from the model cannot be interpreted with certainty. To check for multicollinearity, the Variance Inflation Factors (VIF) have been used (Penn State University, 2018). A VIF value that is higher than 5 indicates potential multicollinearity. A VIF value higher than 10 is a strong indicator for multicollinearity.

4. Results

4.1. Descriptive statistics and Correlations

Through the data collection, initial data on 296 R&D Consortia become available. This data included the rating and involved companies of the R&D Consortia. Additionally, the data of which researchers were involved within the R&D Consortia has been gathered. This has been done by collecting all available data on involved researchers at NWO's research projects in 2016 and 2017. The resulting data contained the information of involved researchers from 1194 NWO projects. The initial data collected from the 296 projects was matched with the data from the 1194 projects to expand the available details. Through the matching of both datasets, 174 unique R&D Consortia have been identified. Throughout all 174 R&D Consortia, the 759 industrial organisations were specified. Some of the specified organisations had been involved in multiple consortia. This meant that some of the organisations were not unique. Of all specified industrial organisations, 563 were unique.

All the identified organisations have been classified according to their SBI code. In total, 138 unique SBI codes have been connected to these organisations. The SBI classification system is built up of multiple levels, containing increasing detail by each subsequent level. The alliance diversity metric has been built on the second and third level of detail, out of 4 levels. These levels have been defined as the main category and subcategory. Of the main category, 47 unique instances were found. The subcategory contained 48 unique instances. Additionally, to estimate the geographical distance of the involved industrial organisations, the locations have been classified according to the COROP regions. These companies were located within 39 unique regions and 138 unique cities or towns. Of the 759 organisations, 121 were located abroad of the Netherlands, of which 114 organisations were unique. These organisations were located throughout 23 unique countries other than the Netherlands. Furthermore, data had been gathered on the scientists involved within these projects. In total, 1601 scientists have been identified in connection to these projects. Of all identified scientists, 868 have been indicated as an active contributor to the scientific research. The non-active scientists have been omitted from the analysis. Additionally, to identify whether the involved research institute had a technical specialization, the research institute connected to the project leaders have been identified. In total, 25 research institutes have been identified, 8 of which had a technical specialization. In consequent steps, the correlations between the different variables have been identified (see *Table 1: Correlation Matrix*).

Table 1: Correlation Matrix

Variable	Min.	Max.	Mean	S.D.	1	2	3	4	5	6	7	8	9
1. Generated knowledge	1	3	2.08	0.53									
2. Economic gains or Societal benefits	1	3	1.35	0.53	.47**								
3. Alliance diversity	0	0.4198	0.30	0.12	.13	-.03							
4. Geographical distance	0	0.4527	0.31	0.12	.10	-.02	.80**						
5. Company involvement	1	3	2.11	0.53	.28**	.20**	-.07	-.03					
6. Funding (x 100.000)	1.97	16.62	6.23	2.65	.15	.14	.20**	.13	-.08				
7. Number of companies	1	14	4.36	2.38	.14	.04	.64**	.66**	-.06	.20**			
8. Number of companies abroad	0	8	0.70	1.04	.02	-.05	.18*	.27**	.05	.03	.23**		
9. Number of researchers	1	15	4.95	2.40	.07	-.00	.19*	.20**	.16*	.21**	.23**	.10	
10. Non-technical research orientation	1	2	1.34	0.48	-.06	-.10	.08	.03	.03	.12	-.05	-.02	.21**

* $p < .05$

** $p < .01$

Within the data, ratings on the involvement of industrial organisations, and the innovative outcomes have been provided. Two separate metrics are available which measure the innovative outcomes, one of which reflects the generated knowledge. The other metric reflects the (potential for) economic gains and benefits to society, thus providing a complete overview of the innovative outcomes. The correlation analysis has shown that the two outcome variables are correlated with the level of involvement of companies. The outcome variables are not correlated with any other variables.

The constructed metric for alliance diversity is significantly correlated with the geographical distance, project funding, number of companies, number of companies abroad and number of researchers. It is expected that an increase in project size leads to an increase in alliance diversity. The probability of the involved companies having a different specialisation naturally increases when a project becomes larger. By inspecting an individual variable which reflects the project size in relation to alliance diversity, this relationship becomes visible (see *Figure 2: Alliance diversity x Number of Companies*). The same effects between project size and geographical distance are expected. A potentially problematic aspect of this would be that alliance diversity and geographical distance are correlated, as the moderation effect between the two is to be studied. Furthermore, the funding variable is correlated with the number of companies and number of researchers. This further coincides with an increase in project size, as the availability of funding naturally attracts more companies and researchers, or vice versa.

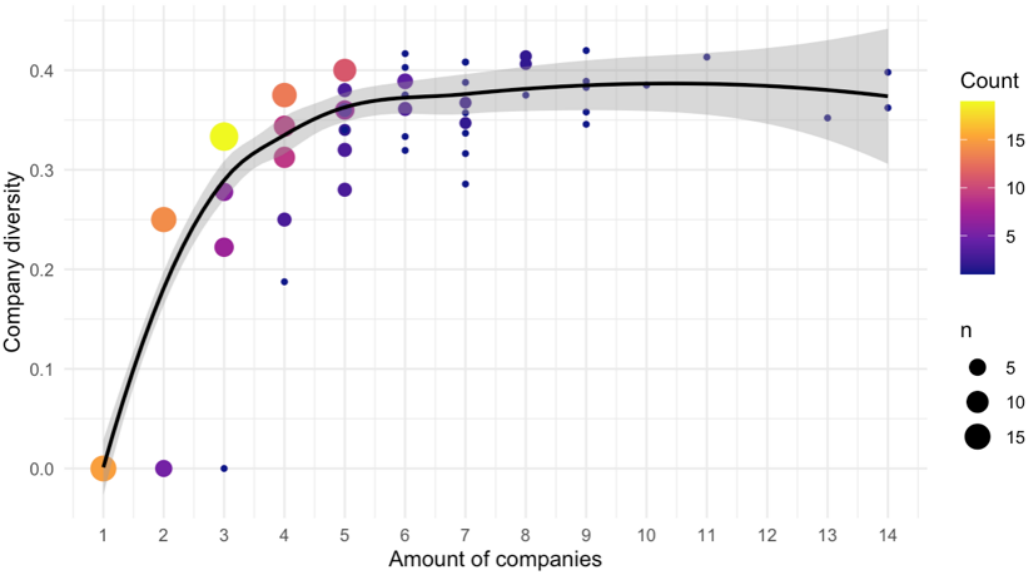


Figure 2: Alliance diversity x Number of Companies

Finally, research institutions with a non-technical research orientation is correlated with the number of researchers. This would indicate that within the observed R&D Consortia, the projects with a non-technical research orientation generally include more scientists.

In addition to the correlation tests, the Variance Inflation Factors have been constructed for all models (see *Table 2: Variance Inflation Factors*). The first two models in which the control variables and main effects are included do not provide significant indicators for the presence of multicollinearity. The values for alliance diversity are higher than 5 within both of these models, which is an indication that some multicollinearity could exist. When the moderating effect of the geographical distance between alliance diversity and innovative outcomes is added to the model, the VIF values become higher than 10. This is an indicator for the presence of multicollinearity within the models which test the third hypothesis.

Table 2: Variance Inflation Factors

Variables	Generated knowledge			Economic gains or Societal benefits		
	Model 1.1.	Model 1.2.	Model 1.3.	Model 2.1.	Model 2.2.	Model 2.3.
Company involvement	1.0728	1.0828	1.1359	1.0627	1.0613	1.0789
Project funding	1.0919	1.1183	1.1975	1.0921	1.1635	1.2468
Number of companies	1.1528	2.4700	2.7019	1.1395	2.5896	2.9577
Number of companies abroad	1.0455	1.0967	1.1031	1.0224	1.0871	1.0913
Number of researchers	1.1304	1.1333	1.1443	1.1485	1.1566	1.1642
Non-technical research orientation	1.0548	1.0813	1.0928	1.0674	1.0883	1.1239
Alliance diversity		5.8879	6.4264		6.8799	7.8797
Alliance diversity squared		4.8825	7.4559		5.6716	8.4948
Geographical distance		3.3565	6.0047		4.2366	7.2229
Alliance diversity x Geographical distance			45.7834			55.5989
Alliance diversity squared x Geographical distance			62.2842			73.5799

Addressing the prevalence of multicollinearity within the final models has been considered. Multicollinearity can be addressed by merging multiple variables through a Principal Component Analysis (PCA). A downside of this would be that the interpretability of the merged variables becomes very difficult. The aim of this research is to understand the effects of the individual variables, so PCA is not suitable. A common issue is that it is unclear what to do about multicollinearity when trying to understand the dynamics of variables. In such an instance, it is recommended to interpret the coefficients with caution (University of Virginia, 2025).

Besides the tests for the main hypothesis, additional exploratory analysis has been performed. The Variance Inflation Factors for the exploratory analysis have been established as well. Within the VIF values for the exploratory analysis, the alliance diversity is higher than 5. This indicates potential presence of multicollinearity (see [Appendix II: Variance Inflation Factors Exploratory Analysis](#)).

4.2. Results of Hypotheses tests

The relationships of alliance diversity and geographical distance with the innovative outcomes of R&D Consortia have been tested through an Ordered Logistic Regression (OLR). There are two metrics used for reflecting the innovative outcomes, both variables have been tested separately. Within the first OLR, the innovative outcome of newly generated knowledge is tested (see Table 3: *OLR predicting Generated Knowledge*). In the second OLR, the innovative output of economic gains and societal benefits are tested (see Table 4: *OLR Predicting Economic gains or Societal benefits*). The results from the OLR's do not provide significant evidence to accept any of the hypotheses. There are some indicators towards the existence of the effect theorised within the first hypothesis, but they require some nuance. No significant indicators have been found for accepting the second hypothesis. The VIF values of the third hypothesis are so high that this hypothesis can neither be accepted nor rejected.

Table 3: *OLR predicting Generated Knowledge*

Variables	Generated Knowledge		
	Model 1.1.	Model 1.2.	Model 1.3.
<i>Step 1: controls</i>			
Company involvement	1.9945 (0.4851) ***	2.0738 (0.4890) ***	2.1378 (0.5009) ***
Project funding	0.3784 (0.1733) *	0.3262 (0.1760) †	0.3379 (0.1823) †
Number of companies	0.3115 (0.1818) †	0.4973 (0.2668) †	0.5576 (0.2793) *
Number of companies abroad	-0.0506 (0.1723)	-0.0178 (0.1771)	-0.0083 (0.1779)
Number of researchers	-0.0321 (0.1855)	-0.0236 (0.1867)	-0.0302 (0.1874)
Non-technical research orientation	-0.3716 (0.3673)	-0.3901 (0.3744)	-0.3758 (0.3766)
<i>Step 2: Main effects</i>			
Alliance diversity		-0.3634 (0.4302)	-0.3092 (0.4487)
Alliance diversity squared		-0.3842 (0.2117) †	-0.2721 (0.2611)
Geographical distance		-0.3547 (0.3258)	-0.3936 (0.4336)
<i>Step 3: Interaction effects</i>			
Alliance diversity x Geographical distance			-0.3756 (0.6756)
Alliance diversity squared x Geographical distance			-0.1069 (0.3148)
Cutoff A B	-2.4087 (0.3072) ***	-2.8278 (0.3908) ***	-2.8606 (0.3950) ***
Cutoff B C	1.7361 (0.2574) ***	1.3878 (0.3142) ***	1.3719 (0.3147) ***
Residual deviance	249.5884	245.7064	245.1157
AIC	265.5884	267.7064	271.1157
n = 174			

a Coefficients are reported with standard errors in parentheses.

† $p < .10$

** $p < .01$

* $p < .05$

*** $p < .001$

When the alliance diversity and geographical distance are included within the first OLR, the quadratic effect alliance diversity shows up as moderately significant. A moderate significance is not enough evidence to accept the first hypothesis. An interesting detail is that the indicated coefficient is negative for the quadratic effect of alliance diversity.

Alliance diversity is theorised to improve innovative outcomes through knowledge exchange. For companies to exchange their knowledge, they need to actively be involved. This would mean that the effects of alliance diversity should be most visible for consortia in which companies have been most involved. When the OLR’s predicted values are displayed for consortia with the highest involvement of companies, the theorised inverted U-shape does become visible (see *Figure 3: Alliance Diversity x Predicted Probability of Generated Knowledge for high Involvement*). When the company involvement is rated as low or medium, this relationship becomes less clear (see [Appendix III: Predicted Knowledge Generation for low and medium Involvement](#)).

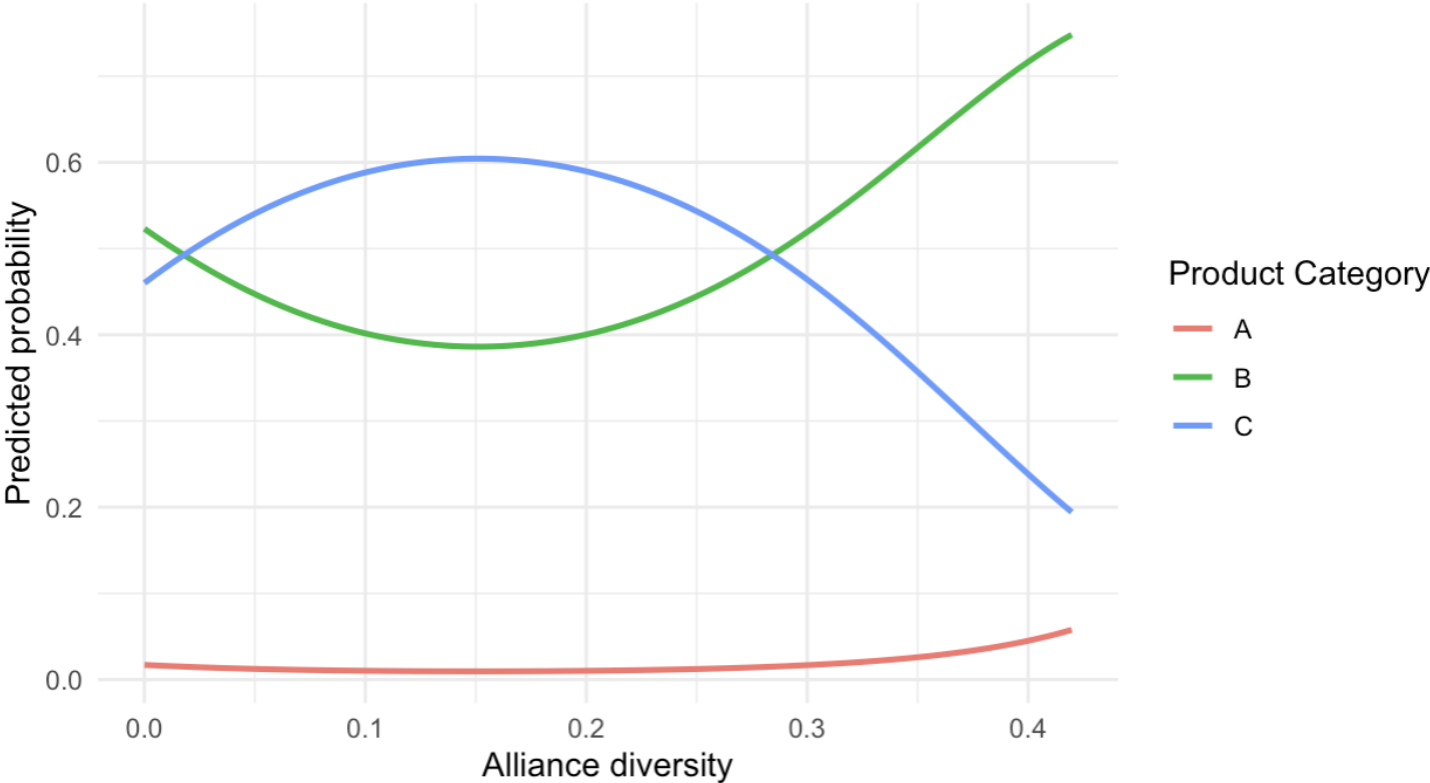


Figure 3: Alliance Diversity x Predicted Probability of Knowledge Generation for high Involvement

Within the projects with the highest company involvement, projects which have none to- little alliance diversity are predicted to perform worse for generating new innovative knowledge. Slightly increasing alliance diversity is then predicted to improve the knowledge generation. At a RaoQ of 0.15 for alliance diversity, the new knowledge generation is predicted to be at its highest. After this point, increases in alliance diversity are predicted to decrease the generation of new knowledge.

The second OLR models test the economic gains and societal benefits (see *Table 4: OLR Predicting Economic gains or Societal benefits*). Within the model in which the main effects for alliance diversity and geographical distance are included, neither show up as significant predictors. This would indicate that within the data, the additional knowledge generation from alliance diversity does not significantly contribute to the innovative outcomes of economic- and societal gains.

Table 4: OLR predicting Economic gains or Societal benefits

Variables	Economic gains or societal benefits		
	Model 2.1.	Model 2.2.	Model 2.3.
<i>Step 1: controls</i>			
Company involvement	1.4826 (0.4932) **	1.4818 (0.4970) **	1.4423 (0.5013) **
Project funding	0.4035 (0.1672) *	0.4440 (0.1730) *	0.4054 (0.1787) *
Number of companies	0.1371 (0.1713)	0.2095 (0.2544)	0.2065 (0.2713)
Number of companies abroad	-0.1756 (0.1822)	-0.1655 (0.1860)	-0.1570 (0.1832)
Number of researchers	-0.1651 (0.1894)	-0.1630 (0.1903)	-0.1531 (0.1898)
Non-technical research orientation	-0.6535 (0.3900) †	-0.6030 (0.3951)	-0.6366 (0.4027)
<i>Step 2: Main effects</i>			
Alliance diversity		-0.1134 (0.4254)	-0.2086 (0.4561)
Alliance diversity squared		0.1175 (0.2076)	0.1500 (0.2553)
Geographical distance		0.1137 (0.3361)	-0.1279 (0.4427)
<i>Step 3: Interaction effects</i>			
Alliance diversity x Geographical distance			0.3548 (0.6834)
Alliance diversity squared x Geographical distance			0.2229 (0.3101)
Cutoff A B	0.7518 (0.2150) ***	0.8989 (0.3028) **	0.8872 (0.3041) **
Cutoff B C	3.6652 (0.4817) ***	3.8340 (0.5323) ***	3.8384 (0.5323) ***
Residual deviance	231.6088	229.8623	229.131
AIC	247.6088	251.8623	255.131
n = 173 (1 observation deleted due to missingness)			

a Coefficients are reported with standard errors in parentheses.

† $p < .10$

** $p < .01$

* $p < .05$

*** $p < .001$

4.2.1. First hypothesis

Only within the OLR which tests the knowledge generation, does alliance diversity show up as moderately significant. This is an indicator that the additional knowledge acquired through alliance diversification within R&D Consortia, is a moderately significant predictor for the innovative outcome of knowledge generation, and not economic- and societal benefits. It is not enough evidence to accept the first hypothesis.

H1: Within R&D Consortia, the alliance diversity of industrial organisations has an inverse U-shape relationship with innovative outcomes.

4.2.2. Second hypothesis

The second hypothesis considers the effects of the geographical distance between industrial organisations within R&D Consortia on the innovative output. The geographical distance between industrial organisations within R&D Consortia has not been found as a significant predictor for innovative outcomes. Thus, the second hypothesis cannot be accepted. Within the OLR that predicts the newly generated knowledge, the geographical distance is a negative and linear predictor. In the secondary OLR for predicting the economic gains and societal benefits, the geographical distance is a positive and linear predictor. Neither of these coefficients have been found as significant predictors for innovative outcomes.

H2: The geographical distance of industrial organisations within R&D Consortia has a negative linear relationship with innovative outcomes

4.2.3. Third hypothesis

The third hypothesis considers if the geographical distance between industrial organisations within R&D Consortia moderates the effects of alliance diversity on the innovative outcomes. No indicators have been found which support the third hypothesis. In the models which included the moderating effect of geographical distance on alliance diversity, significant indicators for the presence of multicollinearity have been found. This means that the results from the models, need to be interpreted with caution. Thus, the third hypothesis can neither be accepted nor rejected.

H3: The geographical distance of industrial alliances within R&D moderates the effect of alliance diversity on innovative outcomes

4.3. Controls

Throughout all tests, the involvement of the industrial organisations shows up as the strongest predictor for innovative outcomes. Higher involvement of industrial organisations predicts higher innovative outcomes. Within the OLR predicting the generated knowledge, the involvement of companies is highly significant at a p value of lower than 0.001. Within the OLR on the economic gains and societal benefits, involvement of industrial organisations had a p value of lower than 0.01 for all models. This aligns with current literature and policy recommendations in which the company involvement is indicated as an important factor for innovative outcomes. Within the models testing the control variables against both variables for innovative outcomes, funding shows up as a significant predictor. Within the observed data higher levels of funding predict higher innovative outcomes. The coefficients and p values are however much lower than that of company involvement, which would indicate that company involvement is a stronger predictor.

Within the model testing the control variables of the OLR predicting the newly generated knowledge, the number of companies shows up as a moderately significant. Funding is a significant predictor for the newly generated knowledge, and the number of companies is correlated with funding. This could provide explainability as to why the number of companies shows up as moderately significant. When the main effects are added in the second model, only the significance of the funding variable decreases. This effect will be studied in greater detail in the exploratory analysis after the main hypotheses.

Within the OLR which considers the economic gains and societal benefits, a non-technical research orientation shows up as a moderately significant predictor. The predicted coefficient is negative, which would indicate that projects run by universities with a non-technical research orientation show lower income within the available data. The significance is moderate, so caution should be taken with interpreting this result. The cutoff values across all models are all significant. This indicates that the models observe significant differences between the different levels of innovative outcomes. The levels of A, B and C for innovative outcomes do not need to be merged then.

A key assumption for running an OLR, is the Proportional Odds Assumption. To verify this assumption, the Likelihood Ratio Test (LRT) has been used. The results for the LRTs were non-significant, which is an indication that the effects of which the independent variables have on the dependent variable, differs for each ordinal outcome. In other words, alliance diversity and geographical distance, do not equally affect each ordinal innovative outcome. So, the effect of alliance diversity and geographical distance, are different for the A, B and C outcomes.

Table 5: Likelihood Ratio Tests

Model	Resid. df	Resid. Dev	Test	Df	LR stat.	Pr(Chi)
1.1	166	249.5884				
1.2	163	245.7064	1.1 vs 1.2	3	3.882068	0.2744834
1.2	163	245.7064				
1.3	161	245.1157	1.2 vs 1.3	2	0.5906321	0.7442963
2.1	165	231.6088				
2.2	162	229.8623	2.1 vs 2.2	3	1.746446	0.6266577
2.2	162	229.8623				
2.3	160	229.1310	2.2 vs 2.3	2	0.7313157	0.6937401

4.4. Exploratory Analysis

The models within the OLR first included the control variables and then the main effects. Within the OLR that predicted the newly generated knowledge, after inclusion of the main effects, the significance of the funding control variable decreased. This effect provided the initial stimulus to continue the exploration on the funding variable. Through some additional exploration, outside of current models, it became apparent that either the funding or alliance diversity provides significant predictability for the generated knowledge. When funding and alliance diversity are both included within the model, the significance for both variables decreased. When only the funding variable is included, this shows up as a significant predictor. When only alliance diversity is included, then this variable shows up as the main predictor. When they are both included within the model, neither show up as a significant predictor, and both become moderately significant. This effect, although not theory- but data-driven, caused the believe that funding could be a moderating variable between alliance diversity and the newly generated knowledge. To test for a potential moderating effect, the same prior models have been run, but this time with inclusion of funding as a moderating variable (see *Table 6: Exploratory Analysis*). When funding is included as a moderating variable between alliance diversity and the generated knowledge, the predictive coefficient shows up as significant. As the construction of this model is data driven, caution need to be taken in the interpretation of the result.

Table 6: Exploratory analysis

Variables	Generated Knowledge		
	Model 3.1.	Model 3.2.	Model 3.3.
<i>Step 1: controls</i>			
Company involvement	1.9945 (0.4851) ***	2.0738 (0.4890) ***	2.0693 (0.4972) ***
Project funding	0.3784 (0.1733) *	0.3262 (0.1760) †	0.7342 (0.2689) **
Number of companies	0.3115 (0.1818) †	0.4973 (0.2668) †	0.4846 (0.2704) †
Number of companies abroad	-0.0506 (0.1723)	-0.0178 (0.1771)	-0.0516 (0.1810)
Number of researchers	-0.0321 (0.1855)	-0.0236 (0.1867)	0.0102 (0.1901)
Non-technical research orientation	-0.3716 (0.3673)	-0.3901 (0.3744)	-0.4394 (0.3800)
<i>Step 2: Main effects</i>			
Alliance diversity		-0.3634 (0.4302)	-0.2905 (0.4364)
Alliance diversity squared		-0.3842 (0.2117) †	-0.4209 (0.2234) †
Geographical distance		-0.3547 (0.3258)	-0.2371 (0.3433)
<i>Step 3: Interaction effects</i>			
Alliance diversity x Funding			-0.4850 (0.3370)
Alliance diversity squared x Funding			-0.4362 (0.1935) *
Cutoff A B	-2.4087 (0.3072) ***	-2.8278 (0.3908) ***	-2.8802 (0.3971) ***
Cutoff B C	1.7361 (0.2574) ***	1.3878 (0.3142) ***	1.4416 (0.3212) ***
Residual deviance	249.5884	245.7064	240.0778
AIC	265.5884	267.7064	266.0778
n = 174			

a Coefficients are reported with standard errors in parentheses.

† $p < .10$

** $p < .01$

* $p < .05$

*** $p < .001$

Additionally, The Likelihood Ratio Test had been performed for the exploratory analysis as well (see *Appendix IV: LRT Exploratory Analysis*). The results for the LRT are moderately significant, which is an indication that the effects of the independent variables differ for the ordinal categories of the dependent variable.

5. Discussion

5.1. The effect of alliance diversity on innovative outcomes

Within the collected data, there were indicators that alliance diversity led to increased knowledge generation. There were no indicators for alliance diversity to affect the economic- and societal output of R&D Consortia. Within the available data, one metric was available which reflected the economic- and societal output. It could be that alliance diversity does lead to either better economic gains, or better societal benefits, if they are considered individually. Within the combined metric, this effect was not visible. The only variables which were found as significant predictors for economic- and societal benefits were the involvement of companies and the consortia's financial resources. It could be that the involvement of companies and financial resources reflect the economic- and societal inputs for R&D Consortia, which could further be studied. Possibly, yet to be identified variables could exist which further improve the predictive capabilities for the innovative outcomes of R&D Consortia. Initially, the theory for an inverted U-shape relationship between alliance diversity and innovative outcomes, was based upon literature the theory of alliance diversity and the knowledge-based view. Within these theories, collaborative R&D arrangements between multiple industrial organisations are considered. While the same relationship was visible within R&D Consortia, it only was visible as a moderately significant predictor for the newly generated knowledge. It was not visible within the other measurement for the innovative outcomes. This potentially has implications for the theory on alliance diversity and the knowledge-based view. It could mean that the availability of knowledge influences the newly generated knowledge of collaborative R&D arrangements, and not all innovative outcomes. Besides these implications to existing theories, it could be possible that the effects of alliance diversity within R&D Consortia are not as strong as within multi-partner alliances.

5.2. The role of geographical distance in R&D Consortia

Within the observations, the geographical distance between industrial organisations has not been found as a significant predictor for the innovative outcomes of R&D Consortia. Within the observations on the moderating effect of geographical distance on the innovative outcomes of R&D Consortia, multicollinearity was present. This indicates that no reliable statements can be made about this effect. The theory that geographical distance is a moderating variable, has largely been based on the theory of alliance diversity. Prior to the consideration of the theory of alliance diversity, theory on the exchange of knowledge has been considered. Within this theory, the geographical distance between industrial organisation is highlighted as a moderating variable for innovative outcomes. Thus, within this research, the geographical distance between industrial organisations has been observed. However, within the observed R&D Consortia, the scientists and scientific institutions were responsible for executing the R&D. As significant multicollinearity was present, it is unclear how the geographical distance between industrial organisations affects the innovative outcomes of R&D Consortia. In future research, it is recommended to observe the geographical distance between the actor responsible for carrying out the R&D activities, and the other actors involved which provide the additional knowledge.

5.3. Financial resources as a moderator for knowledge exchange?

Indications have been found for the existence of funding as a moderating variable between alliance diversity and the generated knowledge. Alliance diversity is theorised to improve innovative outcomes through knowledge complementarity. Knowledge is the primary input for innovative outcomes, and alliance diversification leads to increased knowledge. In this regard, the financial resources should then moderate the actualization of additional knowledge gained

through alliance diversification, to useable knowledge generated by R&D Consortia. If the core of this proposition is considered, then the availability of financial resources, should improve the absorptive capacity of knowledge. It does not seem logical that the existence of financial resources, improves the capacity for knowledge exchange. Financial resources do provide access to other resources. Within scientific research, one of these resources could as an example be scientific instruments. If this extension is placed within the last proposition, then it suddenly does make sense. By considering the scenario of financial resources providing access to other resources, the following hypothetical scenario is created. Alliance diversification creates additional knowledge. To convert the additional knowledge into innovative outcomes, researchers need other resources, which are accessed through the availability of financial resources. Earlier, the example of financial resources providing access to scientific instruments had been used as a method for illustrating a hypothetical scenario. It is unknown what the financial resources have been used for within the observed R&D Consortia.

By reconnecting these observations to the initial theorisation of which resources can enable R&D Consortia, a core aspect becomes apparent. Knowledge is classified as an intangible resource, and financial resources are theorised as a tangible resource. These observations would indicate that intangible and tangible resources do not influence the innovative outcomes of R&D Consortia separately, but that they are interconnected. Other resources than the intangible resource of knowledge and the tangible resource of finances should be identified within the context of R&D Consortia.

5.4. Future research recommendations and implications

Regarding the analysis of innovative outcomes, three different innovative outcomes have been analysed. These are the newly generated knowledge, economic gains and societal benefits. This research has mainly been able to observe the effects of alliance diversity on the generation of new knowledge, as the economic gains and societal benefits were grouped within one metric. Future research should observe the economic gains and societal benefits separately, in relation with alliance diversity within R&D Consortia.

There were no indicators for any effects between the geographical distance of industrial organisations and the innovative outcomes of R&D Consortia. The analysis which included the moderating role of the geographical distance on alliance diversity and the innovative outcomes of R&D Consortia was subject to multicollinearity. Both of these issues relate to the construction of the metric for geographical distance. Within this research, the geographical distance between industrial organisations has been observed. The initial theoretical framework hypothesized an effect through the exchanging of complementary knowledge. However, within the observed R&D Consortia, the available knowledge was not applied at the industrial organisations but instead at the scientific institutions. Future research on the effects of geographical distance on the innovative outcomes of R&D Consortia should consider the distance between the knowledge bases, and the location at which the R&D activities take place.

Finally, the analysis between alliance diversity and the innovative outcomes of R&D Consortia has been expanded to include funding as a moderating variable. The initial theories highlighted the importance of available resources but did not specify that these resources can also be interconnected. Within the analysis, funding as a moderating variable between alliance diversity and the innovative outcomes of R&D Consortia has been found as a significant predictor. This would indicate that the intangible resource of knowledge is moderated by the tangible resource of available funding. Further research could expand upon this observation and study the interconnectedness of tangible and intangible resources within R&D Consortia.

5.5. Conclusion

The results did not provide significant evidence to accept either hypotheses. Indicators have been found towards the influence of alliance diversity on the knowledge generation within R&D Consortia. The observed relationship showed an inverted U-shape, even though this relationship was moderately significant. It is an indicator that an optimum exists for the alliance diversity within R&D Consortia. An effect for alliance diversity on the economic- and societal gains generated through R&D Consortia has not been identified. There were no indicators for a significant effect of geographical distance between industrial organisations on the innovative outcomes of R&D Consortia. The analysis on the moderating effect of the geographical distance between industrial organisations, on the effect of alliance diversity on the innovative outcomes of R&D Consortia was subject to multicollinearity. No reliable statements can be made about the moderating effect of the geographical distance between industrial organisations.

Through exploratory analysis, indicators for the existence of funding as a moderating variable between alliance diversity and the generation of new knowledge have been found. Expanding upon these observations, funding is theorised to not directly moderate the effect between alliance diversity and new knowledge generation, but to provide access to other resources which do. This has yet to be empirically established. Even though current evidence was not strong enough to accept the hypotheses, indicators and nuances for future research have been found.

As initially theorised, the inverted U-shape between alliance diversity and innovative outcomes was visible. The predictive value of this was of moderate significance so the first hypothesis could not be accepted. No significant indicators for the effect of geographical distance on the innovative outcomes of R&D Consortia have been found, so the second hypothesis was not accepted. The final hypothesis which observed geographical distance as a moderating variable was subject to multicollinearity, so no reliable statements can be made about this.

Even though the results of this study need to be interpreted with caution, it does provide preliminary indicators for those involved within the management and establishment of R&D Consortia. Projects with low diversity within the knowledge provided by the involved industrial organisations tend to perform worse for generating new innovative knowledge. When the objective of the R&D Consortia is to generate new knowledge, introducing alliance diversity could be an option for improving this outcome. Pure alliance diversification should not be pursued, as the increased complexity in exchanging additional knowledge will decrease the innovative performance for new knowledge generation.

5.6. Relevance of research topic to Management of Technology

Within the master's program of Management of Technology, students are taught how technology is a resource for firms. This research topic has expanded upon this perspective and further considered which resources are available to firms. The consideration of knowledge as a resource, has been inspired by the contents taught within the Leadership and Technology Management course. The data gathering, processing, and analysis have largely been based upon the contents taught within the Business Analytics course. The Master of Management of Technology focusses upon technology, innovation, economics, commercialization and organisation. This research has been performed on technological R&D Consortia. The main studied variable is that of innovation and touches upon economics. The results from this research could contribute to the commercialization of scientific research and provide knowledge towards the organisation of R&D Consortia.

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Appendix

Appendix I: Data Gathering Process

The core of the data is collected through two annual TTW reports from 2016 and 2017, containing approximately 474 pages with information on research projects. The reported data includes information on which companies were involved in the execution of the projects, and multiple metrics rating the outcomes of the projects. The projects have been rated at the ending and again reviewed 5 years after their ending. The final ratings were used in this research. The data contained within these reports had to be extracted to be useable for analysis. This included the conversion of 306 out of the 474 pages from the 2016 report to a usable Excel file using Adobe Illustrator and Excel Power Query. All the data contained within the remaining 168 pages from the 2017 report had to manually be copy-pasted to an Excel sheet. This conversion resulted in two separate Excel files with data on all the projects within this specific domain in the years 2016 and 2017, including all the involved companies for each project, and a distinct rating on the outcomes for each project.

To fit the data within the specifications of available literature, additional information on the perspective of the involved scientist had to be acquired. By extracting data through NWO's publicly accessible database, a list of all the NWO projects from 2016 and 2017 has been acquired. The data was acquired by calling the NWO API, which resulted in 12 separate JSON files, containing data on 1194 projects from these distinct years. The data included information on all the involved scientists, including which ones were actively contributing to the project. The data within these JSON files was again converted to an Excel file and consequently matched with the projects from the annual reports using the unique Project Identifiers. This meant a dataset had been created containing information on R&D Consortia, the involved companies, the outcomes of the projects, and the specific context of the involved scientists. The yielded data included 174 unique projects within the years 2016 and 2017 within the subdomain TTW of the NWO.

To enable the identification of company core activities, the 759 companies in the dataset were classified according to their SBI and NACE codes. This data is not easily publicly accessible. As these projects are funded through a governmental institution within the Netherlands, the projects were mostly carried out within the Netherlands. However, in some instances companies from outside of the Netherlands were involved. In total, 638 companies were located within the Netherlands and 121 outside of the Netherlands. A couple separate sources were identified which could provide the company SBI. First off, a paid database, accessible through an API, was used to acquire SBI classifications of companies in large quantities (*overheid.io*, 2025). Secondly, a publicly accessible search engine containing information on Dutch companies was used to gather SBI codes for manual lookups on individual companies (*bedrijvenmonitor.info*, 2025). Furthermore, other publicly accessible sources and an LLM connected to multiple search engines was used to find the remaining NACE classifications of foreign companies (*Bizzy.AI*, z.d.; *Google*, z.d.; *OpenAI - ChatGPT*, z.d.).

The main dataset contained only the names and geographical location of the companies. When the *overheid.io* API was called, multiple companies with similar names were returned. A script which estimated the correct company based on the company name and geographical location was written. The logic of this script included calling the API based on the company name and location, locally saving the top matches, and assigning weights to the probabilities of the most likely match. As solely the company name and location are very little information to go off, it meant that a lot of iterations were made. In total, 32144 API calls were made, which yielded the SBI codes of approximately 400 out of the 750 companies. All the found companies were manually inspected to determine if it was correct. After this, the SBI code of approximately 200 Dutch companies had yet to be identified. The SBI codes of the remaining 200 Dutch companies have manually been searched for through a publicly accessible search engine (*bedrijvenmonitor.info*, 2025). In many instances, further investigation was required to determine the actual company, as some companies had changes names, merged with other companies, or simply went out of business. The necessary information on companies which had gone out of business were also accessible through this database, meaning that no companies had to be excluded.

The remaining 121 foreign are not classified according to the Dutch classification system, as they are not Dutch. However, these companies are classified according to the European counterpart, the NACE. The NACE classification closely resembles the SBI classification, the descriptions for activities are often the same. However, the numeric identifiers assigned to the classifications often differ slightly. This meant that for all the identified NACE codes, the correct SBI counterpart had to be manually identified. By accessing publicly available search engines and employing the use of an LLM connected to multiple search engines, the NACE codes of the remaining companies were identified (*Bizzy.AI*, z.d.; *OpenAI - ChatGPT*, z.d.). The identified NACE codes for all companies were manually inspected to determine if they correctly reflected the core activities of the companies.

The identified SBI codes for all the companies were then visually inspected. After this inspection, it was identified that for approximately 80 companies, the SBI code indicated a financial holding. As a financial holding does not correctly reflect the core activities of a company, another inspection of these 80 companies was necessary to correctly identify their core activities. Previous steps were repeated, including an inspection of secondary SBI codes, which led to correctly identifying the correct activities for the remaining companies. In the end, the SBI code for 4 out of 759 companies could not directly be identified, as the companies could not be found. However, documentation on the activities of these companies was found, and through this, an estimation of a correct SBI classification was made. This final step then meant that collecting the required data for identifying the core activities of the involved companies within the specified TTW projects was complete.

Furthermore, within the data on the involved companies, the geographical location was available. To expand upon the city names, the COROP regions have been gathered. The Central Bureau for Statistics offers a dataset including city names and their respective COROP classification (CBS, 2025c). Additionally, two datasets including the city names and the respective COROP regions from 2016 and 2017 are offered (CBS, z.d.). This dataset was used

to match the geographical location of individual companies with the connected COROP region. The dataset only contained COROP regions for cities, and not for villages. For approximately 100 villages, the overarching municipality was identified to correctly match the village to the COROP region. This final step meant that the gathering of all the necessary data for estimating innovative outcomes, alliance diversity and geographical distance was complete.

Appendix II: Variance Inflation Factors Exploratory Analysis

Table 7: Variance Inflation Factors Exploratory Analysis

Variables	Model 3.1.	Model 3.2.	Model 3.3.
Company involvement	1.0728	1.0828	1.0876
Funding	1.0919	1.1183	2.4003
Number of companies	1.1528	2.4700	2.5080
Number of companies abroad	1.0455	1.0967	1.1214
Number of researchers	1.1304	1.1333	1.1540
Non-technical research orientation	1.0548	1.0813	1.0855
Alliance diversity		5.8879	6.0243
Alliance diversity squared		4.8825	5.4820
Geographical distance		3.3565	3.6662
Alliance diversity x Funding			3.6222
Alliance diversity squared x Funding			5.1184

Appendix III: Predicted knowledge generation for low and medium involvement

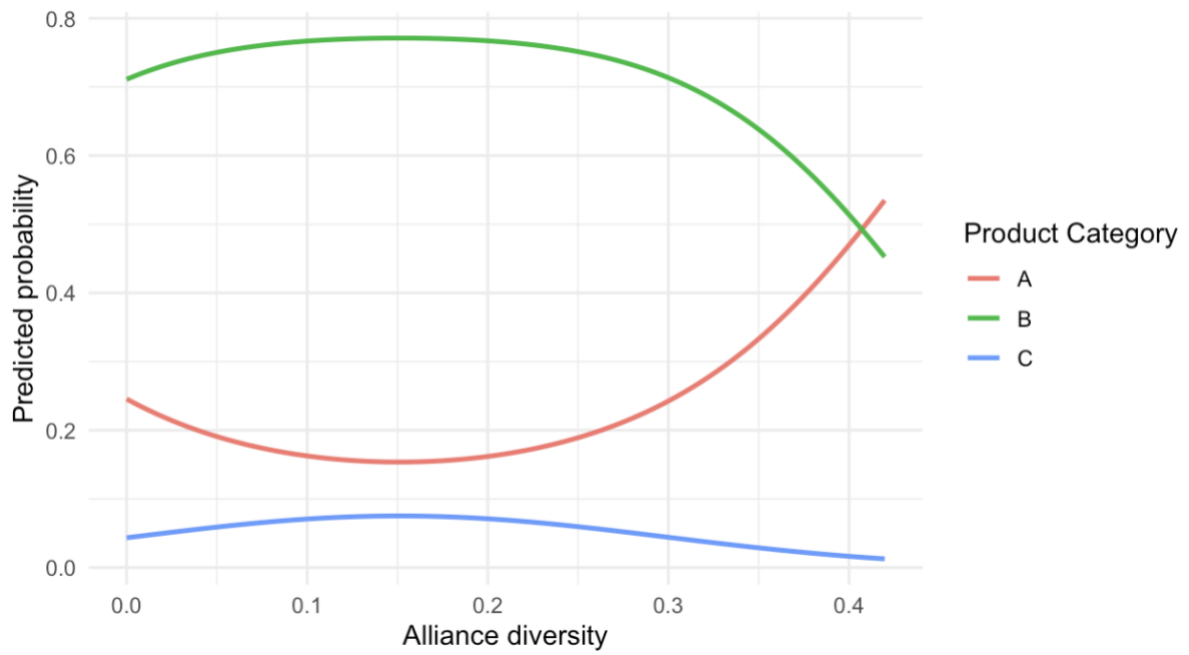


Figure 4: Alliance Diversity x Predicted probability Generated Knowledge for Low Involvement

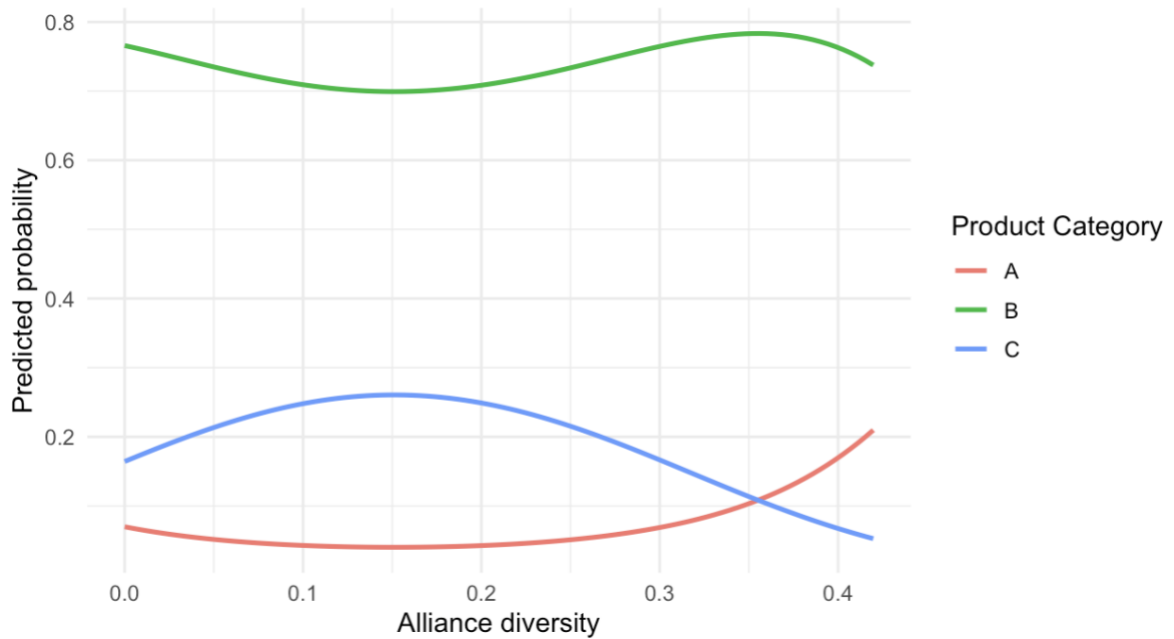


Figure 5: Alliance Diversity x Predicted probability Generated Knowledge for Medium involvement

Appendix IV: LRT Exploratory Analysis

Table 8: Likelihood Ratio Test Exploratory Analysis

Model	Resid. df	Resid. Dev	Test	Df	LR stat.	Pr(Chi)
3.1	166	249.5884				
3.2	163	245.7064	3.1 vs 3.2	3	3.882068	0.2744834
3.2	163	245.7064				
3.3	161	240.0778	3.2 vs 3.3	2	5.628607	0.05994646