A conceptual review of R&D spillover, and a case study of the smartphone industry.

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Abstract

Firms cannot capture all value generated from their R&D activities, so R&D spillovers occur. Understanding the magnitude of spillovers will help companies understand their absorptive and appropriability capacity. The field is also of great interest to policymakers to foster domestic innovation and attract foreign R&D inflows. In addition, the world is getting increasingly globalized, and a rising need for understanding international spillovers occurs. This paper is divided into two main sections, (1) explores the concept of spillovers, methodologies for identification and various transmitters of spillovers (2) explores the theories through two case studies in the smartphone industry.

As empresas não podem capturar todo o valor criado pelas suas atividades de R&D, provocando R&D spillovers. Torna-se assim importante compreender a magnitude de spillovers, a fim de ajudar as empresas a entenderem as suas capacidades de absorção e apropriabilidade. Este tema é de igual interesse para os decisores políticos, a fim de promoverem inovação doméstica e atrair fluxos estrangeiros de R&D. Além disso, com o englobamento do mundo, emergiu uma necessidade de melhor compreender ocorrências de spillovers internacionais. Este artigo encontra-se dividido em duas secções principais, (1) explora o conceito de spillovers, metodologias para identificação e vários transmissores de spillovers (2) explora as teorias por meio de dois estudos de caso na indústria de smartphones.

Keywords: Spillovers, R&D, Knowledge Production Function, Smartphone
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Table of contents

1.Introduction

This paper is divided in to two separate sections. Section one is exploring the concept of R&D spillovers through a literature review. The purpose is to outline characteristic of spillovers, how to detect them and understand the channels in which they be transferred. Section two is a case study of major players in the smartphone industry, and examining how the theory applies to them.

Firms engaging in R&D activities and investments cannot appropriate all the value generated from their R&D activities. When a firm cant appropriate all the value, it will result in a spillover from their R&D activities (Bernstein, J. I., & Nadiri, M. I., 1998).

Spillovers are considered a business externality. "OECD defines externalities as a situation when the effect of consumption or production of goods/services imposes cost or benefits on others which are not reflected in the prices" Externalities can take forms as both positive and negative externalities (Directorate, OECDS, 2002).

Mohnen (2019) indicates that spillovers are an important factor in R&D-based growth models. He also argues that the theory of spillovers is a double-edged sword. On the positive side, knowledge can be transmitted between agents, generations or "when rents occur because of imperfect price discrimination". R&D spillovers can be seen as a source of productivity gains. However, spillovers can also be negative, leading to decreasing returns, obsolescence and market stealing.

Through the literature review it is clear that the literature on spillovers come in waves of three branches. The earliest literature focusses mainly in spillover within industries, and without the inclusion of a spatial factor. Second wave of literature starts to give more attention towards interindustry spillover, and start to include a geographical variable, to measure the spillover in a spatial context. The last wave of literature is focused on global spillover, given the fact that the economies are getting globalized, and trade is increasingly happening across borders.

In 1890 the English economist Alfred Marshall developed a theory of knowledge spillovers. The theory was later extended by the two economists Kenneth Arrow (1962) and Paul Romer (1986) (Carlino.G., 2001). In the article "Growth in cities", the authors combined Marshalls, Arrows and Romers' thoughts into what is known as the MAR theory of knowledge spillovers. The MAR theory of knowledge spillover implies that clusters of entities within the same industry foster innovation and adaptation. The proximity between entities will affect the quality and quantity of knowledge transfers/spillovers. Thus greater the proximity, the greater the spillover will be.
The MAR theory suggests, likewise Schumpeter, that a local monopoly is a stronger vehicle for growth than local internal competition. The theory argues that a monopoly restricts knowledge transfer to others. When the innovator can absorb all value and externalities, innovations will be created, and this results in overall growth (Glaeser. et al., 1992)

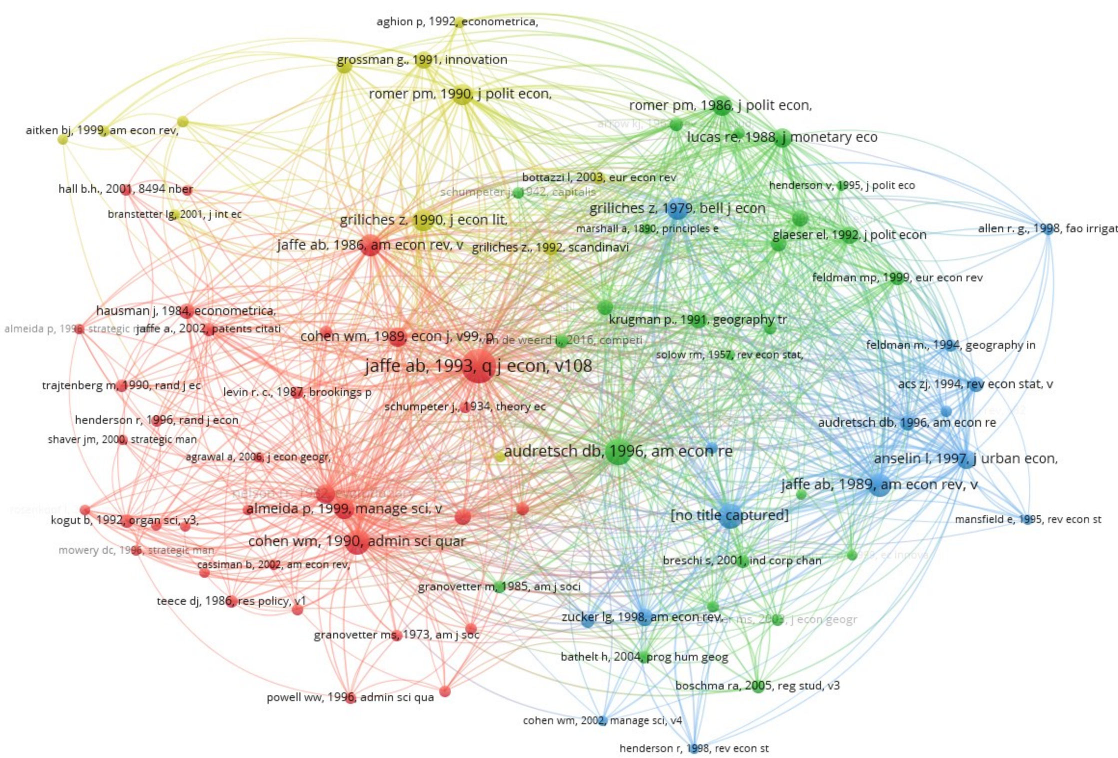
Jacobs (1969) developed a spillover theory that deviated from what MAR and Porter suggested. Where MAR and Porter focus on spillovers from specialized entities in the same industry, Jacobs focuses on knowledge transfer among firms from different industries and argues that these transfers are important to promote growth and innovation. According to her theory, diversity fosters innovation as people with different backgrounds exchange ideas from different perspectives and maximize the innovation output. Jacobs explains the phenomenon with the example of the bra industry. The industry of bras is an externality of dressmakers' innovations and not the lingerie industry. Likewise, Porter, Jacobs favours local competition over local monopoly, as it fosters the adoption rate of new technology (Glaeser. et al., 1992, Carlino.G., 2001).

Porter (1989) supports MAR's argument that knowledge spillovers in geographical clusters of specialized industries stimulate growth. He, however, argues that competition within the clusters, as opposed to local monopoly, will foster new innovations and increase the adoption rate. Porter, among others, provides examples of the Italian ceramics industry, the gold jewellery industry, and the German printing industry to be geographically clustered industries in fierce competition. He argues that the industry has experienced rapid growth due to the introduction of new technologies, and entities compete to be the new innovator. (Glaeser. et al., 1992, Carlino.G., 2001)

2.Literature review

The literature review for this thesis was done using Web of Science and VosViewer. The method used in this project is to create a database on Web of Science based on a keyword. This first search was based on the keyword "Knowledge Spillover". In order to find the knowledge base and the assumed original thoughts, I performed a co-citation analysis, with the unit of analysis being cited references. I then examined the authors with the highest total link strength and recorded the most cited articles.

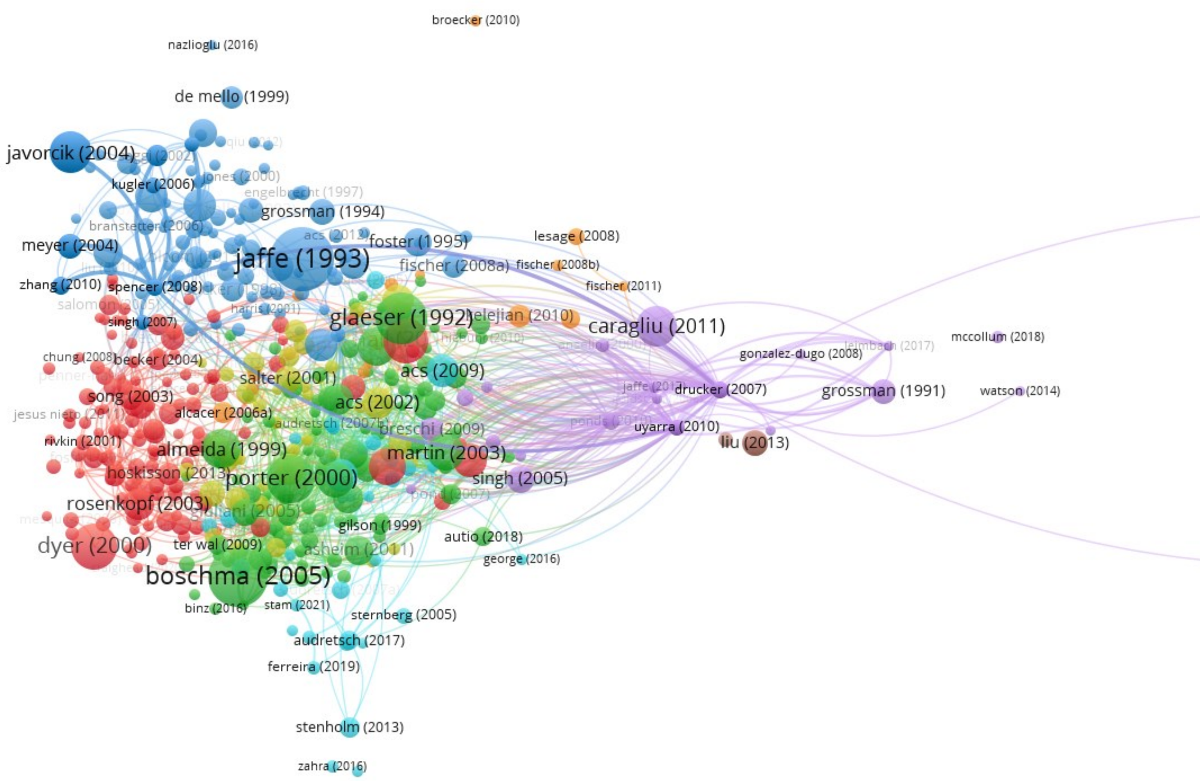
Figure 1



Source: Own contribution through VosViewer

In order to then find the research front and, by that, the newest and most influential articles in the field, I did a bibliographic coupling analysis, using documents as the unit of analysis. By doing so, I could choose the most influential articles within the scope of my research and work my way down to the knowledge base and its founders. By doing so, I work my way down through time and try to reach the same starting point/authors. This ensured that I examined the boundaries of the field of knowledge spillovers. The process was replicated with different search terms as the paper progressed, as new information and branches were discovered. Search terms include: “Knowledge Production Function”, “International Spillovers”, “Global Spillovers”, “Spillovers” + “patents citation”, “spillovers” + “patent”, and “R&D spillovers”.

Figure 2



Source: Own contribution through VosViewer

Carlino, G. (2001) wrote a conceptual article discussing the relationship between economic growth and the concentration of firms and people in cities. This relationship is centered around knowledge spillover. Carlino gives a historical recap of economic spillover theories, starting with MAR spillovers. There are two theories on different types of spillovers: the MAR spillovers and the Jane Jacobs spillover. MAR spillovers focus on firms in a common industry, whereas Jane Jacobs's spillover focuses on the diversity of industries in an area. The article briefly reviews the literature based on examining spillovers through patents. Carlino concluded that patent activity is positively correlated with population density.

Glaeser, E. L., Kallal, H. D., Scheinkman, J. A., & Shleifer, A. (1992) review three fundamental theories explaining externalities concerned with spillover: the MAR theory, Porter's theory and Jacob's. Next, the authors examine the spillover effect on generating growth in cities. Cities are interesting because spillovers are particularly effective there, as communication between people and the industry density is high. The research is based on industry growth in 170 American cities between 1956 and 1987.Their paper findings suggest that local competition and urban variety positively affect employment growth in industries. Furthermore, the findings suggest that knowledge spillovers might significantly impact inter-industries more than intra-industries, consistent with Jacob's findings.

Griliches, Z.'s (1979) publication is centered around the production function method to measure the returns of R&D and the implications that arise in the process. Griliches highlights a conceptual issue of the production function: the definition of the output and input variables. Some sectors experience issues quantifying their real output levels, such as health, defense and space. Defining and measuring the stock of R&D capital leads to implications in measuring the spillover effect. Such implications are (1) The result of R&D activities is often seen years after the expenditure. (2) Past research depreciates and becomes obsolete. (3) Spillover effect implicates the measurement of R&D capital and vice versa.

Griliches Z. (1992) reviews the basic model of R&D spillover in order to find empirical evidence of their existence and magnitude. He argues that two types of estimates are generally found in the literature. (1) estimates of social returns from a particular innovation or group of innovations whose effects are limited to a specific industry and can be measured there. (2) Regression-based estimates of overall returns to a stream of outside R&D expenditures. Griliches argues that he was the first to use a regression-based method to measure the spillover effect (1964). Griliches notes that regression-based studies can have measurement issues in determining output and how R&D “capital” is constructed and depreciated. Griliches proposes two methods to construct spillover stocks/pools and five methods to construct a variable measure of the technological proximity between firms and industries. In general, Griliches believes that many individual studies have flaws, but the overall conclusion is that spillovers are present and they are essential.

Mohnen, P. (2019) wrote a chapter on various technological indicators. The authors review innovation inputs and innovation outputs. In general Mohnen is concerned about how we measure the different indicators, and to what extent do we asing strengths and weaknesses to them. It is an important topic so that we have a consequent and universal understanding of how to interpret variables for economic analysis. Lastly, Mohnen points out the relationship between innovation and productivity growth.

Griliches, Z. & Lichtenberg, R., L., (1984) wrote a chapter in NBER’s volume “R & D, Patents and Productivity. Their chapter revolves around the relationship between R&D and productivity growth at the industry level. The chapter discusses the R&D data available, the total factor productivity data available and the modeling of the relationship of R&D to productivity. The primary source of R&D data on the industry level is based on the surveys conducted by Census Bureau for the National Science Foundation. An issue in these surveys is that firms perform R&D targeted industries other than those surveyed. As for modeling, the authors raise the question of how much lag there should be on the R&D but gives it little attention. Finally, the authors perform a Cobb-Douglas production function to test the relationship between R&D and growth and conclude that the relationship is still significant.

Pakes A. and Griliches Z. (1984) discuss the knowledge production function from a theoretical perspective. They created a simplified path analysis diagram of the overall model. Through patenting behavior of 121 firms during 1968-75, they examined the relationship between the variables in the knowledge production function. They conclude that patents are a good indicator of knowledge transfer between firms.

Jaffe, A. B. (1986) quantifies the effect on a firm's R&D productivity and the role of other firms' R&D activities (spillovers). Utilizing patent data Jaffe, A. B. determines a firm's technological position and, therefore, the technological proximity between firms. This proximity is used to construct a variable concluding the existence of spillovers. The potential spillover pool is defined as a weighted sum of other firms' R&D, with weights proportional to technological proximity. The author develops three equations that examine the relationship between R&D activities and spillovers on a firm's patent applications, market value and profits. Through the analysis, Jaffe concludes that spillover affects all three equations. Firms that are in clusters of companies with high levels of R&D, on average, receive more patents per dollar of R&D and receive a higher return on R&D, both in market value and profits. On the other hand, firms with low R&D efforts that cluster with R&D-intensive firms will suffer from lower profits and value.

Bernstein, J. I., & Nadiri, M. I. (1988) that the previous studies treat spillover as a single variable. Therefore, it is impossible to distinguish individual firms or industries as sources of spillovers. The publication examines the effects of interindustry R&D spillovers in five high-tech industries. The authors estimate a production cost function for each industry. The sample period was from 1958 to 1981, and the industries were: chemical products (SIC 28), non-electrical machinery (SIC 35), electrical products (SIC 36), transportation equipment (SIC 37), and scientific research (SIC 38). The authors conclude that increasing the receiving spillover would decrease variable costs for every industry examined. The highest effect was chemical products (1961) when receiving spillovers from scientific instruments. A one per cent increase in spillovers caused the variable cost to decline by 0.208 per cent. They conclude that receiving spillovers emanates from a narrow range of industries, as three industries only had one spillover source.

Bernstein (1989) refers to previous studies done by Griliches (1979) and Spence (1984) as the papers validating that a distinctive feature of R&D is a firm's inability to appropriate all of the benefits of its R&D investment. Beside Bernstein's and Nadiri's (1988) work, Griliches argues that the prior research defined R&D spillover as a single aggregate, meaning that individual industries were not treated as separate sources of spillover. This publication aims to estimate the effect of inter-industry R&D spillovers on the production cost of nine major Canadian industries. Data is collected between 1963 to 1983, and the output is measured by gross output. The author estimates that the gross private returns on R & D are two and a half to four times greater than rates calculated for physical capital. Bernstein's findings showed that R&D spillovers influence all nine industries, and six industries were affected by more than one spillover source. The cost reduction resulting from the receiving spillover ranged between 0.005 per cent and 1.082 per cent. The publication highlights the importance of distinguishing industries as sources of R&D spillovers.

Wallsten J. S. (2001) examines knowledge spillovers using a geographic information system and firm-level data. By calculating the geographical distance between each firm pair, Wallsten can test for spillover effect. The research question of the publication is about whether or not the probability of entering the Small Business Innovation Research (SBIR) program is higher or lower when nearby firms win the grants. The concluding remarks are that firms clustered with former SBIR winners are likelier to enter and win the grant. In addition, firms no more than a fraction of a mile from each other strongly predict winning rewards.

Karlsson C. et al. (2012) quantitatively review the empirical literature on spatial knowledge spillovers. Through a meta-analysis, the authors determine the extent to which these spillovers have been documented in Europe and their spatial reach. The publication's first part is to define types of spillovers, how embodied they are, and methodologies to measure them. Spillovers can either be transaction-based, transaction-related or pure spillovers. As for methodologies, the authors highlight patent citation analysis and the knowledge production function approach.

Breschi S. and Lissoni F. (2001) review the empirical literature on localized knowledge spillovers and their spatial boundaries. The authors identify two main characteristics in the methodology of measuring spillovers. Firstly there is a large contribution of publications using the knowledge production function, and then there is the more innovative branch of patent citation analysis. The authors call it more of an innovative branch because there is not a universal approach to this, and the publications are using a variety of models and approaching data differently. The authors concluded that the notation of localized knowledge spillovers is largely abused, and that creates conceptual confusion on the topic and research agendas. Distinguishing between pure spillovers and rent spillovers is very difficult and causes confusion. Lastly, the authors raise questions about the measurement of input variables. How are we defining the geographical dimension, how do we assess the labor market's ability to transfer knowledge, and how to distinguish between different types of knowledge flows?

Ali-Yrkkö J. et. al. (2021), is examining the spillover-effect associated with employee mobility. The authors research the effect of employees leaving Nokia throughout their growth and decline period. Through a quasi-experiment based on difference in difference methodology they test the treatment of hiring an ex-Nokia employee, on five different variables: Value added, Net sales, Labor productivity, employment, and operating profit (EBIT). They divided the treatment into three specifications: (i) Number of ex-Nokia employees hired, (ii) years of job tenure (1990-2017), (iii) years of job tenure through Nokia's growth (1990-2008) and decline (2009-2017). They find statistical significance correlation between multiple variables and treatment specification, leading to the concluding that tacit knowledge spill over through employee mobility.

Feldman P. M. (1999) reviews the recent empirical studies on innovation spillovers and agglomeration. The review is centered around the methodology of measuring geographically mediated spillovers and productivity studies that include a geographic dimension. The first part of the publication introduces four methodologies for defining and measuring spillovers. (1) The knowledge production function, (2) Paper trails left by patent citations, (3) Ideas in people/spillovers embodied in people, and (4) Ideas in goods.

Jaffe, A. B., Trajtenberg, M., & Henderson, R. (1993), research spillover and its spatial boundaries. Through a patent citation analysis, the authors follow the paper trail that knowledge flows create. Due to the rich geographic information patents contain about their inventors, it is possible to follow these trails through a spatial lens. The data is based on patents assigned to universities and a sample of domestic (U.S) corporate patents. They find evidence that citations to domestic patents are more likely to be domestic and even from the same state and SMSA (Standard metropolitan statistical area). Lastly, they conclude that localization fades slightly over time.

Dumont M. and Meeusen W. (2000) prepared their paper for the OECD-NIS focus group. First, a literature review is done to answer the question, “how embodied is knowledge spillover?” Next, the authors estimate knowledge spillovers through R&D cooperation. The underlying assumption is that the number of cooperative links between firms can be seen as a proxy for knowledge flows. Dumont and Meeusen constructed a matrix of intra- and inter-sectoral knowledge flow. The authors claim that using their matrix can eliminate the dependency on distance measures.

Guimón (2011) highlights how FDI in R&D was in the past primary demand-driven, meaning that asset exploitation is often seen in the manufacturing process. Guimón highlights that supply-driven FDI in R&D is becoming increasingly important. This involves the exploration of knowledge and specialized clusters. In order to foster inward and outward innovation, Guimón developed a taxonomy of policies to benefit from the globalization of corporate R&D. The taxonomy includes four policy objectives: "*Enhance the R&D investment climate", "Promote inward FDI in R&D", "Absorb the benefits from inward FDI in R&D",* and *"Absorb the benefits from outward FDI in R&D".* Overall the article highlights how policies and policymakers can strengthen national innovation systems and European innovation systems.

Dunning J. H. and Lundan S. M. (2009) review evidence of MNEs' internationalization of their R&D activities. The paper identifies three historical phases of diversification and internationalization. The first phase is the lead market seeking and adaptations of products the parent organization supplies. The second phase, from the 1970s to the early 1980s, is to exploit the scale and scope of economies with existing technology. The third phase is exploiting the interrelatedness between technologies. The authors provide arguments for and against the decentralization of R&D versus centralization. The paper reviews the history of patenting of foreign countries versus domestic countries. The authors conclude with two significant implications for host countries' policymakers.

Bitzer J. and Kerekes M. (2008) conclude that since the early nineties, there has been an increase in empirical studies examining the extent to which trade can be a source of knowledge spillovers. This publication examines the extent to which FDI can be a channel for knowledge diffusion, based on industry-level data of ten manufacturing sectors in seventeen OECD countries from 1973 to 2000. To answer this question, the authors apply a Cobb-Douglas production function approach. The authors find evidence that host countries benefit strongly from inward FDI-related spillovers. However, they do not find evidence that outward FDI positively affects the home country.

Cincera M. and Potterie B. V. P. D. L (2001) review micro and macro levels studies evaluation of foreign R&D's impact on domestic productivity growth. The overall convergence of the studies is that international spillovers are significant, but the authors identify several issues and propose further research to eliminate these. They categorize spillovers into rent spillovers as part of economic transactions and knowledge spillovers due to technological proximity. The issues highlighted are related to the approach and models estimated, the weight used when computing foreign R&D capital stock, and the definition of channels knowledge can be transmitted through. The authors call for more research at the macro level and in the service sector.

Coe D. T. and Helpman E (1995) present a model based on the production function. The authors study the dependencies between a country's total factor productivity on domestic and foreign R&D capital. The data is based on OECD countries between 1971 and 1990. Through their estimates, there is an indication that foreign R&D has a positive effect on domestic production, which increases with the country's openness.

Eaton J. and Kortum S. (1995) examine technological innovation and its effect on domestic growth and growth abroad. A patent analysis examines 19 OECD countries' relative productivity and capacity to absorb technology. The period is 1986-1988, and the output is real GDP per worker. The authors find the ideas are very mobile internationally, and besides the United States, growth is largely dependent on research done outside domestic borders.

Maurseth P. B. and Verspagen B. (2002) examine European knowledge flows through the patent citations analysis approach. The authors refer to Griliches' (1979) definition of spillovers, namely pure spillover or rent spillover. The patent database is constructed from all European patent applications from 1979-1996. Through descriptive statistics, it is possible to see that intra-national citations are more frequent than national citations. The authors concluded that geographical distances have a negative impact on knowledge flows. Knowledge flows are larger within countries than between regions of different countries. Even regions sharing the same language but not the same country have a higher flow of knowledge. Knowledge flows are industry specific, geographically bounded and influenced by language.

Phene, A. & Almeida, P.. (2008) examine subsidiaries of MNCs' role in the globalization of innovation through patent data and patent citations. The papers developed ten hypotheses which regression models examined. The model seeks to find the correlation between the scale/quality of innovations and different independent variables. Through the authors' analysis, they conclude that knowledge assimilated from other firms in the host country positively affects the scale of innovation. Sourcing capability has a significant impact on the scale of innovation. The combinative capability has a significant effect on the scale of innovation. Knowledge assimilated from the home country significantly impacts the quality of innovation. Finally, both sourcing capability and combinative capability significantly impact the quality of subsidiary innovation.

Sanna-Randaccio F. and Veuglers R. (2007) research the trade-offs MNEs face when deciding when to organize R&D as either centralized or decentralized. The authors argue that supply-side motivations increasingly drive R&D internationalization. The publication provides a game theoretic setup, considering two countries. The first country is the home base of monopolistic MNE. In the second country, the MNE is running a subsidiary, where there also is a local producer. Centralization of R&D can limit the spillover from MNEs to local firms and restrict absorptive capacity.

Engelbrecht H-J (1997) publication is an extension of the publication done by Coe D. T. and Helpman E (1995). Engelbrecht examines the international R&D spillovers among 20 OECD countries plus Israel. The author includes a human capital variable, which captures innovation outside the R&D sector, which is not usually captured by formal R&D. The inclusion of the human capital variable results in a smaller coefficient for domestic R&D capital and international R&D spillovers; however still highly statistically significant. The publication supports the findings done by Coe and Helpman and concludes that general human capital affects total factor productivity and acts as a vehicle for international knowledge transfers.

Florida, R. (1997) research is centered around examining the landscape of foreign-affiliated R & D laboratories in the USA. The paper examines the R&D laboratories' scope, motivations/activities, performance, and organizational structure. The research design is based on a survey sample of 186 R&D laboratories. Florida research concludes that the three main motivations are technology-oriented: "Developing new products, obtaining information on scientific and technological development, and accessing a talent pool of high-quality scientists, engineers and designers. This is a remark on the importance of both the demand and supply sides. Furthermore, he concludes that FDI in R&D are heterogeneous according to the industry, and the R&D labs are working relatively autonomously. The latter imposes little effort to transfer management style from home country to host country.

Gerybadze and Reger (1999) examine the internationalization of R & D in 21 large corporations in Europe, Japan, and the U.S. The authors suggest that a paradigm shift is happening. Moving away from the "*traditional paradigm",* where technology and knowledge transfer are one-way transactions. Concepts and knowledge centers are created in the dominant home base and later replicated abroad, known as *outward learning.* The "*new paradigm"* is characterized by cross-functional learning, a combination of inward and outward learning, and knowledge hubs at several geographic locations. The authors developed a framework to serve as a managerial tool in the decision-making process of internationalizing R&D. Their framework includes four generic strategies based on the speed of innovation cycles and the location of critical assets.

Keller W. (2000) estimates the amount of spillover from R&D in nine OECD countries from 1970-1995. He examines whether knowledge spillovers are local or global by computing the distance between countries. Keller makes two significant findings, (1) that technological knowledge is, to a considerable extent, local, as the benefits from foreign spillovers are decreasing over space. For example, a 10% increase in the distance leads to a 0.15% decrease in productivity. (2) Through the period examined, Keller concludes that technological knowledge has become more global. From 1970 to 1995, the negative correlation between distance and spillover effect declined by 20%.

Wooster R. B. and Diebel D. S. (2010) review the literature on spillovers generated by foreign direct investment in developing countries. The authors construct a meta-regression analysis based on 32 studies and 141 regression results. The analysis findings show weak evidence that domestic firms gain from incoming FDI in the same sector. Results suggest that spillovers are more present in studies measuring the effect of FDI spillovers on output and are more likely to be significant and positive for Asian countries.

Ugur M., Churchill S. A., and Loung H. M. (2019) did a meta-analysis of 60 empirical studies to find evidence on spillover heterogeneity and statistical power. The authors' findings are that the average spillover effect is positive and heterogeneous. They note that the actual effect is less than reported in most reviews. The spillover effect is usually smaller than that of their own-R&D efforts. They also conclude that the effect is more significant among OECD countries/firms/industries.

Neves C. P. and Sequeira N. T. (2018) review the literature concerning a knowledge production function and perform a meta-regression analysis. They justify the importance of the research field due to its contribution to understanding endogenous growth theory and understanding spillover can serve as guidance for policymakers in terms of tax policies or subsidies. The authors identify five branches of literature associated with estimating a knowledge production function. (1) dealing with spatial spillovers, (2) estimation of knowledge production function in firms/industries, without the inclusion of spillovers, (3) estimation of knowledge production function based on Aghion and Howitt (1992), without the inclusion of spillovers, (4) a branch using time-series to estimate relations between aggregate knowledge and resource, without the inclusion of spillovers, and (5) estimation of the knowledge production function with an intertemporal spillover effect. Their meta-analysis focuses on branch five.

3.Spillovers as a concept

3.1 Types of spillover

When talking about R&D spillover or knowledge flows, it is important to distinguish between pure spillover and knowledge flows that are transaction-based or knowledge flows that are a by-product of other transactions (Breschi and Lissoni, 2001)

In an attempt to outline the challenges associated with measuring R&D effectiveness on growth, Griliches (1979) defines spillovers as "the effect of "outside" knowledge capital - outside the firm or industry in question - on the within-firm industry productivity. In his work, he identifies two types of spillovers, namely pure spillover and rent spillover. The rent spillover is when R&D-intensive inputs are bought for less than their full quality price. He argues that the surplus is not a pure spillover but more a matter of measurement issues of capital equipment. If we were to buy R&D inputs at their "quality" price, we would not see any spillover. True spillovers are ideas captured by R&D departments in industry i from the research result in industry j. This definition of pure knowledge spillover, however, leaves out intra-industry spillovers. Griliches and Licthenber (1984) define "Pure knowledge transfer" as "the cross-fertilization of one industry's research program by developments occurring in other industries".

Karlsson and Johansson (2006) distinguish between three types of knowledge flows that may generate knowledge spillover: transaction-based flows, transaction-related flows, and pure spillover flows. The classifications are seen from the perspective of a firm, and each classification can have different types of knowledge flows. The classification and the related knowledge flows are presented in the following table.

Table. 1

Knowledge flow classification	Knowledge flow description
Transaction-based flows:	Flows that stem from knowledge providers that sell knowledge, to be used as an input in the firms R&D activities Flows that are in the form of inventions/innovations, to be sold to the firm. E.g. licensing of patents Knowledge flows in cooperative R&D, where there is a mutual benefit or cost, regulated by explicit or implicit contracts. When a firm obtain knowledge via merger or acquisitions
Transaction-related flows:	Knowledge flows that are embodied in the delivery of inputs, from an input provider to the firm. When providing inputs, the input provider unintentionally spills over knowledge to input-buying firm. In the course of supplying inputs to another firm, knowledge from the input-buying firm spills over unintentionally to the input-selling firm.
Pure spillover flows:	Knowledge flows that unintentionally spills over from one firm to a competitor in the same industry Knowledge flows that unintentionally spills over among firms in different industries.

(Source: Karlsson and Johansson p.17 Entrepreneurship and dynamics in the knowledge economy)

From the firm's standpoint, knowledge flows can be distinguished between upstream, downstream and horizontal knowledge flows. Upstream and downstream knowledge flows are associated with the knowledge embedded in inputs, products or licenses/patents. Upstream knowledge flows can help gain access to suppliers' knowledge and technology embedded in R&D inputs bought by the firm. Downstream knowledge flows include the direct sale of knowledge. This can be either by selling licenses or as embedded in products. Horizontal knowledge flows include pure spillover flows, either intended or unintended, between firms in the same industry. Upstream and downstream knowledge flows are inter-sectoral and horizontal knowledge flows are intra-sectoral. (Karlsson et al., 2012)

I believe that Karlsson et al. neglect the possibility of pure spillover flows upstream and downstream. A firm might spill knowledge and technology information in either direction of the value chain. The question is whether the knowledge is valuable for the other actor and do they even have the appositive capacity to recognize and utilize the information. Nevertheless, the spill will be there anyway. A company wishing vertical integration would favour these upstream/downstream spillovers. A given firm's rate of R&D spillover might endanger its position in the industry. If all of their R&D activities spill out, they will not have any firm-specific knowledge or a competitive advantage.

3.2 The empirical methodologies

Feldman (1999) proposes four approaches to measure geographically mediated knowledge spillover: (1) Geographic knowledge production functions (KPF), (2) Paper trails; information left in patent citations, (3) Ideas in people, and (4) ideas in goods. Feldman (1999). Reviewing the literature makes it clear that there is a dominance for using KPF, as in the form introduced by Griliches (1979), or with some modifications. In the literature, it is clear that several studies have adopted a cobb-Douglas production function.

The cobb-Douglas production function is widely used to represent the relationship between production output and two or more inputs, such as physical capital and labour. The most simplified version of the formula is the production of a single good with two independent variables.

$$Y = AL^{\beta}K^{\alpha}$$

Y = is the total production of that single good (The real total value produced in a year)
L = Labor (In the original model it is hours in a year)
K = Capital input.
A = Total factor productivity.
β and α is output elasticities of labor and capital.

The first study to use a knowledge production function to measure spillover from R&D and innovation activities was by Griliches (1979). His work derives from a production function connecting the measure of outputs, at the macro or micro level, as a function of inputs, X, K, and u.

$$Y = F(X, K, u)$$

Y is a measure of production output, X stands for conventional inputs such as capital and labour, K is a measure of aggregated technical knowledge determined by current and past R&D

expenditures, and u is a measure of all other unmeasured variables contributing to output/productivity.

Griliches creates a simplified model within-industry spillover effect as:

$$Y_i = BX_i^{1-y}K_i^yK_a^u$$

Y_i is the output of ith firm, X_i is the conventional input, with other words standardize knowledge in the industry, K_i is the firm specific knowledge, K_a is the aggregate knowledge in the given industry. Griliches (1979) rewrote the formula in order to find a way to measure K_i the aggregated technical knowledge. K_a the sum of all of firm specific knowledge:

$$K_a = \sum_i K_i$$

Under the assumption that own resources are allocated optimally, and every firm in the industry faces the same relative factor prices, he computes a model to measure the aggregated knowledge borrowed by ith industry from all available sources:

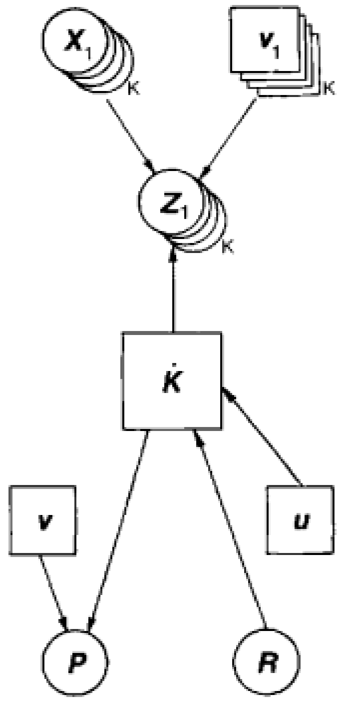
$$K_{a_i} = \sum_j w_{ij}K_j$$

Where K_j measure the knowledge available in these sources, w_{ij} is the weighting function, measuring the amount of knowledge borrowed from jth industry, by ith industry[1].

Pakes and Griliches did further research on KPF, introduced by Chriliches(1979). The authors made a simplified path diagram of the overall model. See figure 1.

Figure 3

[1] To get a more comprehensive explanation of the rewriting of the formula, consult the work done by Griliches (1979)



A simplified path analysis diagram of the overall model.

Source: Pakes A. and Griliches Z. (1984)

Define K as the level of economically valuable technological knowledge and K= dK/dt as the net growth in knowledge per unit of time. K is central unobservable, which, together with the observables, the X's, and the disturbances, the V's, determines the magnitude of several interrelated indicators of invention and innovation, the Z's. The latter include the firm's stock market value, the productivity of traditional factors of production, and investment expenditures on traditional capital goods.

The author's main focus in the report is on the lower half of the diagram (K̇ and below).
From the diagram, we can see that K̇ is produced by what the authors call KPF. K̇ is a result of past research expenditures, R, and a disturbance term, u, that will translate into new inventions. The disturbance term, u, is the combined effect of the inherent randomness in the production of inventions and the effect of other nonformal R&D inputs. P represents patents as the imperfect indicator of new innovations and inventions. V represents the noise between K̇ and P.

In Grilliches work "The search for R&D spillovers" (1992), he formulated a production function on a firm level, including the aggregate knowledge pool within the industry. Griliches states that "the level of productivity achieved by a firm or industry depends not only on its own research but also on the level of the pool of general knowledge". This has similarities to Jaffes' idea of a "spillover pool".

Neves and Sequeira (2018) identify five branches within the literature using KPF.

Table 2

1)	A branch associated with spatial spillovers
2)	A branch associated with estimation of KPF in firms and industries. This branch does not usually include spillover effects (Crepon et. al. 1998)
3)	A branch using the KPF following Aghion and Howitt (1992). Does not include estimations of knowledge spillover.
4)	A branch using time series to estimate the long-run correlation between aggregate knowledge and resources. This branch does not estimate spillover effects.
5)	A branch that estimates a KPF with an intertemporal knowledge spillover.

In the 1980s, Adam Jaffe started to be one of the leading voices in the field of innovation studies. In the literature, there was also an increasing focus on the geographical extent of knowledge spillovers.

Jaffe (1986) attempts to make empirical evidence of R&D spillovers by examining a firm's patents, profits and market value. His work builds on the basic approach suggested by Griliches. However, he further develops it by estimating a "spillover pool" variable, which is the *"weighted sum of other firm's R&D, with weights proportional to the proximity of the firms in technology space."*

Jaffe concludes that firms which conduct their research in areas where there is a high degree of research done by other firms, on average, have more patents per dollar of R&D, and they have a higher return on their R&D in accounting profits and market value. Conversely, firms with low R&D intensity suffer from lower profits and valuation if their neighbours heavily invest in R&D. He estimates that if everyone increases their R&D expenditures by 10%, the aggerated profits will increase 30%, with 1/3 coming from spillovers. Jaffe’s' work is based on the assumption that firms have a higher probability of absorbing spillovers from firms that are in close technological proximity. Jaffe et al. (1993) started to raise the question of where spillovers go. Is it available for everyone around the world? In order to answer these questions, the authors introduced a patent citation analysis. Using patent citations makes it possible to measure the geographical extent of spillovers, as a patent application must contain citations to the prior art.

According to Jaffe (1986), a limitation of the patent class systems is that it is technology based. There can be some similarities between patent class and industry, but directly mapping patent classes to industries is not unique in either direction. The fact that patent classes are not directly transferable to industries is often seen as a limitation for economic research. If one is trying to draw conclusions about a whole industry, this might as well be true. Another implication of using patent citations as a measure of knowledge spillovers or flows is that the inventor or patent examiner might have a shortcoming in understanding the prior art and, by that, missing out on citations. Patent citation also does not account for non-patented knowledge or unpublished patents, which might implicate identifying certain knowledge flows. Regression-based measurement meets the issue of how R&D is measured and how the measurements available capture the real contribution of R&D. Also, how is R&D capital constructed, deflated, and depreciated.

Bernstein and Nadir (1988) estimate the effect of spillovers by using the production cost function. They examine high-tech industries in the United States and find that variable cost declines due to spillovers. This finding is true for all of the six examined industries. For example, chemical products' variable cost in 1961 declined by 21% when spillovers increased by 1%. Labour and materials demand is also affected by spillovers and decreases the demand. On the other hand, the demand for physical capital increases when spillover increases.

Bernstein (1989) estimated interindustry R&D spillover's effects on production costs in major Canadian industries. He argues that research and development capital accumulation in one industry can affect the production cost of a given firm operating in another industry. Per definition, pure knowledge/R&D spillover is there to take for no cost. A company's inability to appropriate all of the value of its own R&D will then reduce R&D costs at a different firm and, by that, increase the profit margins.

Wallsten (2001) Uses a different and more simplistic approach to examine spillovers at the firm level. Using a geographic information system and a firm-level dataset, he calculates the distance between each firm pair to determine co-location. The author then tests if there is a higher probability of getting SBIR grants if a firm is in a cluster with former winners. The author concluded that clusters and proximity of SBIR winners and other firms would affect the probability that a firm will enter the program and win awards. Firm co-location within a small radius will strongly predict winning SBIR awards.

3.3 Spillover channels

As mentioned by Feldman (1999), spillovers can be embodied in traded goods and ideas in people. Karlsson and Johansson (2006) define embodied spillovers as part of transaction-based flows or semi-embodied when they are a by-product of a transaction. Van Pottelsberghe (Year) defines embodied spillovers as part of an economic transaction. In general, there is a consensus in the literature about how we recognize embodied spillovers, which can be summed up using Griliches's definition of rent spillovers. He defines embodied spillovers as related to the purchase of equipment, goods and services. Further defines all embodied spills as rent spillovers.

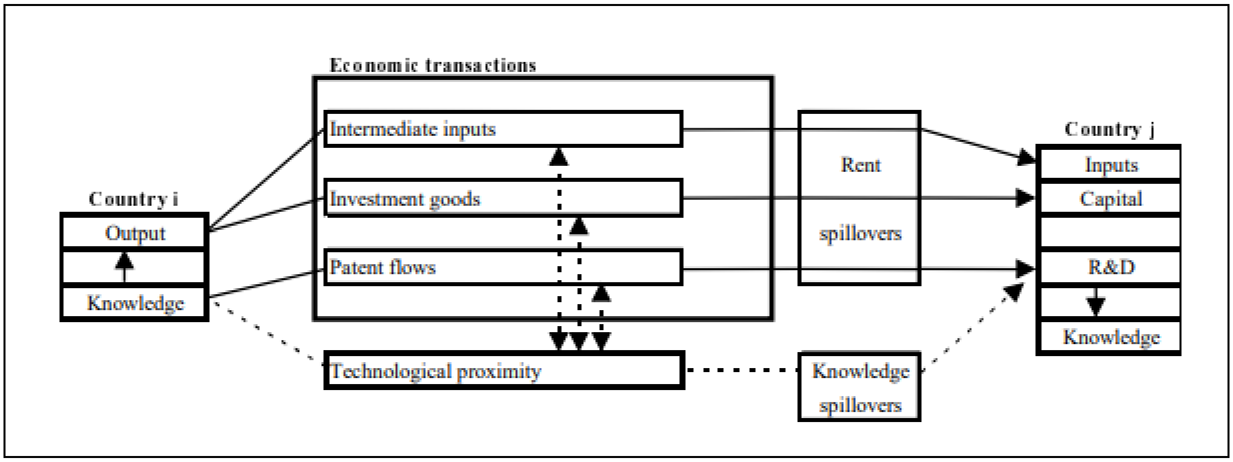
Embodied spillovers are often easier to measure than pure spillovers. Embodied spillovers are often measured through trade and input-output flows. (Dumont and Meeusen, 2000) As embodied spillovers follow transactions and are found as a product of trade, they should not be neglected by policymakers. When posing trade barriers, a country might limit the knowledge flows embodied in international trade.

Breschi and Lessoni (2001) call for a broader understanding of how knowledge is transmitted rather than only looking at a restricted set of measures. Karlsson C. et al. (2012) outline different mechanisms that transfer knowledge and technology.

- *Education*
- *Communication channels that are interactive and high breadwidth*
- *Deliberate policy (e.g., organizations setting up scouting and knowledge intelligence units)*
- *R&D collaboration*
- *Special activities of people in order to obtain and disseminate knowledge (e.g. gatekeepers, see Allen 1977)*
- *Mobility of people with the relevant knowledge and skills,*
- *Trade in goods and services*
- *Trade in knowledge and technologies,*
- *Direct investments*
- *Intra-firm knowledge management,*
- *Imitation and reverse engineering (cf. Verspagen 1994)*

Each channel or mechanism can be seen as partly independent, as they, in most cases, are somewhat interconnected.

Figure 4



Source: Cincera and Potterie, (2001)

The figure captures the channels of knowledge flows from a firm's R&D activity in country *i,* to a firm in country *j*. In this case, the model is focused on the macro level and cross-border flows. However, the model can also be evaluated as an inter- and intra-industrial model. The model assigns rent spillover to three different economic transactions. Inputs-related rent spillovers are defined by the country *j*'s import of intermediate inputs from country *i*, or firm j purchasing technology goods from firm *i*. Investment goods rent spillovers are defined by transactions of investment goods from country *i,* to appear as capital in country *j*. Patent flows are defined by licensing agreements between country *i* and country *j*. If the patent were completely sold, it would be considered as investment goods and appear as a capital asset. When these economic transactions are taking place, rent spillover may or may not occur, depending on the transaction price charged by the producing/selling firm.

The dotted line represents the potential knowledge spillovers that may take form through various channels. The level of potential knowledge spillovers is determined by the technological proximity between the country, industry or firm, depending on the scope of the analysis. As mentioned, knowledge spillovers are not always directly embodied in economic transactions. It may either be pure knowledge spillover or combined with economic transactions.

4.Case studies

4.1 Nokia case

"*Do workers hired from superstar tech firms contribute to better performance*?" Ali-Yrkkö, Hasanov, Kuosmanen and Pajarinen ask themselves this question in their article *Knowledge Spillovers From Superstar Tech-Firms: The Case of Nokia* (Ali-Yrkkö et. al, 2021) In order to understand why Nokia is an excellent case for measuring spillovers transferred by people, it is necessary to understand the history of Nokia.

Nokia was founded in 1865 as a single paper mill operation and has since been operating in a wide range of industries, such as rubber, cable, paper, tires, television and mobile phones (Our history, Nokia). A company so agile and transformative would need to borrow knowledge from outside the organization, as it would be nearly impossible to be an internal champion in each industry. However, this needs to be documented and documenting the spillover effect of their activity in the mobile phone sector is a good case. At the beginning of the 1990s primary focus was telecommunication. In 1991 the first official phone call based on the GSM network, also known as 2G, was performed using Nokia equipment (Our history, Nokia). In 1992 Nokia was the first to mass-produce a GSM phone (Nokia 1011) (Križanović, 2021). As a result of the introduction of the iPhone in 2007, a revolution was about to occur in the mobile phone market. Design, functionality and features were to change forever, set new standards for what a phone was, and brought the word smartphone. In response to the decreasing sales and increasing competition from iOS and Android, Nokia entered a partnership with Microsoft in 2011. In 2014 Nokia sold its entire mobile and devices division to Microsoft (Our history, Nokia).

It is safe to say that Nokia has played a significant and dominant role in the evolution of the mobile phone market, but in the end, it was nothing more than a sinking ship. One primary reason for Nokia's success was that it heavily invested in R&D. In 2008, Nokia's R&D expenditures accounted for 37 % of the total R&D expenditure in Finland (Ali-Yrkkö et. al, 2021). For instance, annual R&D expenditures (Worldwide) increased from 1.76 billion euros in 1999 to an all-time high of 5.97 billion in 2008 and a significant decrease after the sale of the mobile division in 2014 (Appendix 1). The closure of the division led to a massive labor movement. The article *"Do workers hired from superstar tech firms contribute to better performance?"* examines how tacit knowledge spillovers from Nokia when these employees need to find a new employer. This relates to Karlssons C. et al. (2012) proposed channels and mechanisms *"that support and facilitate the transfer and diffusion of tacit as well as codified knowledge".* One of the mechanisms highlighted is the "*mobility of people with the relevant knowledge and skills"*.

The authors point out two issues affecting the identification of spillover effects. The first issue is a matter of the direction of causality. *For example, "Does the knowledge spillover improve firm performance, or is it the selection of more skilled workers into high-performing firms?".* In other words, is the former Nokia employee contributing to the performance of hiring firms, or are productive firms hiring ex-Nokia employees? The second issue is to choose the appropriate measure of spillovers. Spillovers are not a directly observable phenomenon, which is why the literature often uses a proxy for them (Ali-Yrkkö et. al, 2021).

The author's empirical analysis is divided into two stages. They combined coarsened exact matching (CEM) with a difference in difference analysis. The direct identification of spillovers rests on a quasi-experimental difference in difference methodology. By doing so, it is possible to examine if there is any difference between a treated group and a non-treated group, and in this case, the treatment will be hiring ex-Nokia employees. These actions try to eliminate the aforementioned first issues. The second issue is dealt with by using job tenure as a knowledge carrier and measuring for spillover. By doing so, they also eliminated the possibility that Nokia would hire more skilled workers in the first place. The intensity of treatment, such as years of job tenure at Nokia, allows them to differentiate the learning at Nokia, thus the knowledge spillover, from the workers' initial knowledge. The sample is divided into two groups, (i) all hires and (ii) specialist hires. Besides the two different samples, they included three specifications of treatment intensity: (i) Number of ex-Nokia employees hired, (ii) years of job tenure (1990-2017), (iii) years of job tenure through Nokia's growth (1990-2008) and decline (2009-2017). Finally, the authors examine the impact of the intervention, in this case, the arrival of ex-Nokia employees, based on five variables related to performance: Value added, Net sales, Labor productivity, employment, and operating profit (EBIT) (Ali-Yrkkö et. al, 2021).

In the sample of *all hires*, the authors find evidence supporting the existence of positive spillover embedded in the mobility of Nokia employees. For example, for specification (i) number of hired Nokia ex-employees, they find that a one percentage change in the number of hired ex-Nokia employees on average causes 0.071% and 0.11% age change in value-added and operating profit, respectively, at a significance level of 5%. However, the impact on employment, labor productivity and net sales were insignificant (Ali-Yrkkö et. al, 2021).

For specification (ii) job tenure total, they find that a one percentage change in the treatment intensity on average causes a 0.009% change in employment at the significance level of 10% and a 0.043% change in net sales at the significance level of 5%. Further, it caused a 0.035% and 0.046% increase at the significance level of 1% in value-added and operating profit, respectively (Ali-Yrkkö et. al, 2021).

For specification (iii), where the job tenure is analyzed separately for the growth and decline periods at Nokia, they observe differences in spillovers. They only find an impact on one of the outcome variables for the growth period. A one percentage change of job tenure (growth), on average, causes a -0.019% change in employment, at a significance level of 1% at the treated companies. They find a significant impact on employment, value-added, net sales and operating profit for the decline period. A one percentage change in job tenure (decline) caused a change of 0.071%, 0.101%, 0.078% and 0.085% for employment, value-added, net sales and operating profit. Employment and value-added are at a significance level of 1%, operating profit 5% and net sales 10% (Ali-Yrkkö et. al, 2021).

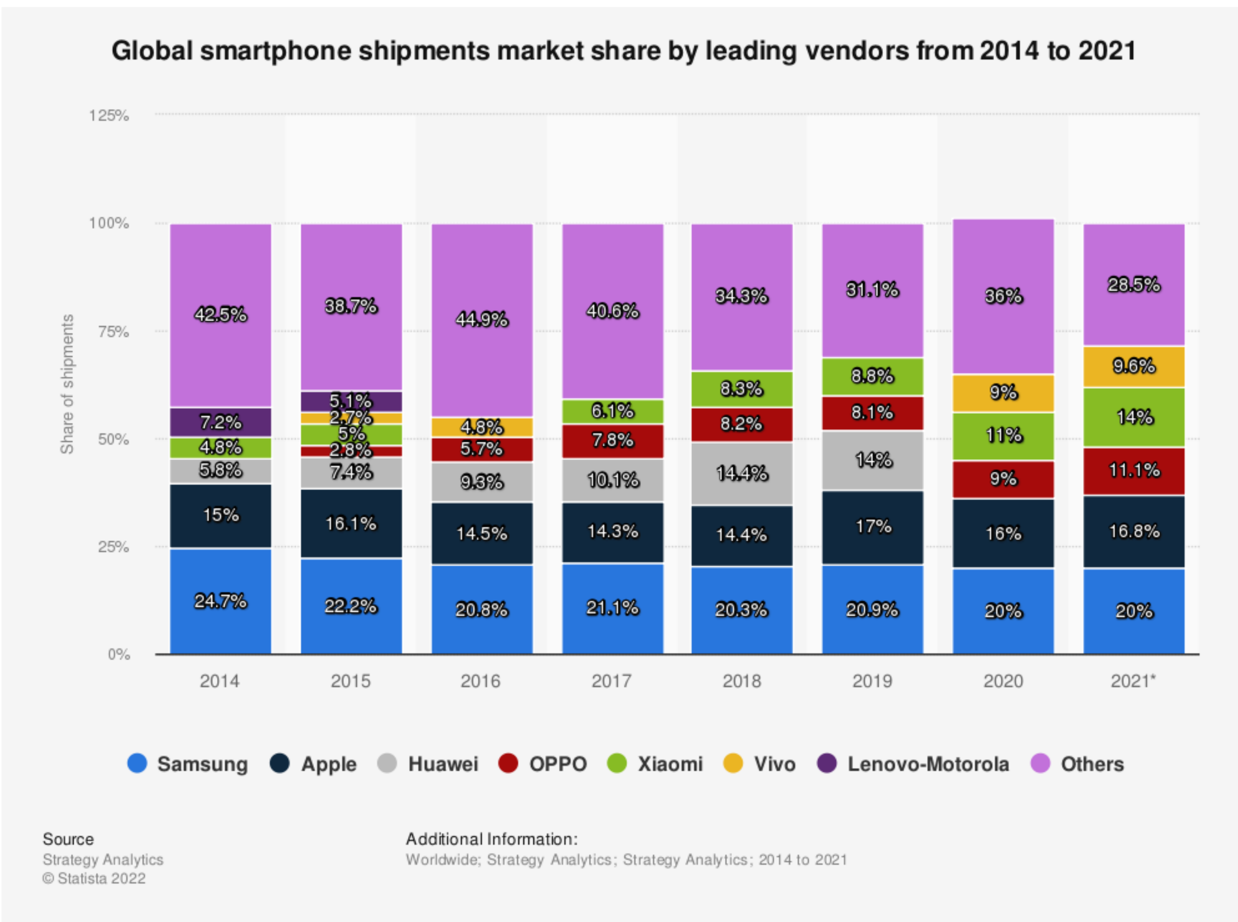
In the sample of *specialist hires,* there is found to be a less significant correlation between treatment intensity and the outcomes of interest. For specification (i) number of hired Nokia ex-employees, they find that a one percentage change in treatment on average increases values added by 0.066% at the significance level of 10%. For specification (ii) job tenure total, they find that a one percentage change in treatment on average increases values added by 0.026% at the significance level of 10%. For specification (iii), the results show the same results as of the sample All hires, supporting the different impact based on the growth year or the decline of Nokia's success (Ali-Yrkkö et. al, 2021).

4.2 Apple – Samsung

4.2.1 The partnership

A further look into the smartphone industry reveals multiple spillovers, predominantly from the two most prominent actors in the market, namely Samsung and Apple. Nevertheless, spillovers are seen on the hardware and software sides, where IOS and android are the strongest players in the market.

Figure 5



(Source: Statista)

Samsung and Apple have a stronghold in the European and North American markets. However, in a global market, the competition has intensified as companies such as Xiaomi, Vivo, and

OPPO have gained increasing market shares. As a result, they are especially losing market shares towards these new entrants.

Looking at the European and North American markets, it is clear that Samsung and Apple dominate the market, and the market can be categorized as oligopolistic. In the fourth quarter of 2021, Apple and Samsung had 31% market shares in Europe based on shipped products (Appendix 2). North America's accumulated market share based on shipped products in the fourth quarter of 2021 is 84%, with 24% for Samsung and 60% for Apple. In general, both actors are performing stronger in the US than in Europe; (consult appendix 3 for a comparison)

Apple and Samsung have a rich history of suing and counter-suing each other. This history is an example of technological knowledge spilling out from the organization, and often that knowledge is embedded in the product itself. The fact that knowledge is embedded in products and technology, free for anyone who wishes to seek that knowledge, is why we restrict the use of that knowledge through patents and copyrights. So even if the knowledge is available to anyone, it does not mean everyone is entitled to use it. Patent infringement is at the core of the long-lasting battle between Apple and Samsung.

The patent war between Apple and Samsung is part of a more complex patent war between multiple smartphone manufacturers and software providers. Throughout this chapter, the patent war will refer only to the case between Apple and Samsung. It is easy to see why a patent war has emerged in the smartphone industry when one understands that a single phone can be touched by as many as 250.000 patents, according to an estimate by RPX, a patent licensing company (O'Connor, D., 2018)

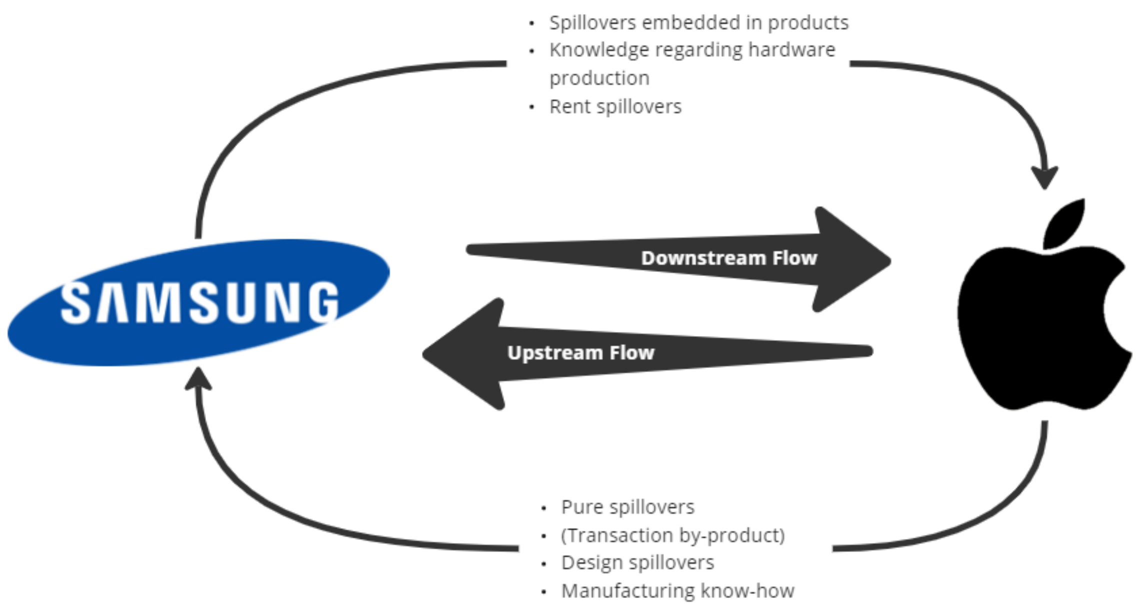
The patent war can be assumed to originate from an example of horizontal upstream spillovers. This assumption is based on the fact that Apple and Samsung were trusted partners before the patent war started. The partnership between Apple and Samsung started in 2005 when Apple decided to discard hard disc drives for their products and instead use flash memory chips. Because of that, Apple was looking for a long-term partner that was financially strong and able to deliver without shortage (Gupta et al., 2013).

In 2005 the market of flash memory was divided between NAND flash memory and NOR flash memory. NAND flash memory was experiencing growth while NOR flash memory was in decline. Samsung was a manufacturer of flash memory in 2005, with a total market share of 35% of the total market (EDN, 2006) and about 50% of the NAND flash memory (Gupta et al., 2013). Therefore, choosing Samsung as the memory supplier for Apple's future products seemed wise, as they could grow simultaneously.

The partnership between Apple and Samsung also extended into the production of mobile application processors. For the early iPhones and iPod Touch, Samsung designed and manufactured processing chips for Apple according to the desired specifications from Apple. This R&D collaboration had its time between 2007 and 2010, and the partnership was terminated at the point where Apple sued Samsung for patent infringement (Kang, J., 2020).

When entities engage in partnerships, it comes along with some risks and dependencies. This particular partnership gave Samsung and Apple valuable insight into each other's strategies and operations. The two can be seen as complementary regarding their weaknesses and strengths. Apple owns a strong consumer brand with a proven track record of pushing products to end consumers. Samsung had a strong history of producing technological components without the same market know-how. In other words, Samsung emphasizes upstream knowledge, and Apple emphasizes downstream knowledge.

Figure 6



(Source: Own creation)

Figure 6 gives an overview of which types of spillovers are in place and their direction of them. For example, the knowledge flow from Apple to Samsung is considered an upstream knowledge flow, and from Samsung to Apple is a downstream knowledge flow.

On April 22, 2011, Apple filed a lawsuit against Samsung. The claims mainly revolved around the design of Samsung's galaxy mobile product line, including the Galaxy S smartphone and the Galaxy Tab tablet. On May 18, 2011, Samsung was ordered to provide Apple samples of the announced Galaxy S", Infuse 4G and the Infuse 4G LTE smartphones, as well as the Galaxy Tab 8.9 and Galaxy Tab 10.1 tablets. The same day Samsung filed a court motion for Apple to provide samples of the unannounced iPhone 5 and iPad 3 prototypes. This motion was later denied. This kind of disclosure can be a channel for spillover.

The partnership has provided Apple with valuable information about the manufacturing of hardware. These spillovers have been on an organizational/strategic basis and embedded in the products. According to Cincera and Potterie (2001), the spillovers embedded in the products themselves can be seen as intermediate inputs and therefore are categorized as rent spillovers. This is supported by Karlsson and Johanneson (2012), who categorized it as transaction-related, as the input-delivering company unintentionally spills over knowledge to the input-buying firm. Both classifications fall under Griliches's concept of rent spillover and could be seen as pricing failure as the knowledge is not factored into the product's price. An aspect that also could be considered, which has yet to be discussed in the literature, is process management. This is one of the greatest spillovers from Samsung to Apple. In manufacturing companies, keeping strict manufacturing process management is of utmost importance. This is based on the assumption that a manufacturing company would like to keep the incremental production cost low to achieve economies of scale and, therefore, competitive advantage.

Because of these spillovers, each company strengthened its operations' weaknesses. For example, it made it possible for Apple to move the production of memory and processors in-house because of their insight into the manufacturing processes. Likewise, Samsung was able to move towards an end-consumer product because of the spillover from Apple.

4.2.2 Employee mobility

As shown in the case of Nokia, employee mobility can facilitate spillovers and affect the company's profitability. Apple and Samsung also have a history of hiring each other's employees. The question can again be raised: Are they doing so because these companies are hiring the best employees or because they are ex-employees of the opponent? Some examples of employees turning their back on the company in favor of joining the competitor are:

In December 2013, Samsung hired Tim Gudgel, former director of Design (US & EU) at Apple. According to his LinkedIn, his role at Apple was to manage the design and development efforts of the retail store fleet. At Samsung, he was hired as Vice President and general manager with the responsibility of developing the North American group, creating flagship stores and distributing flagship products (Gudgel, T., n.d) (Wakabayashi, D., 2013). The responsibilities can be seen as equal in the two roles and is an opportunity for Samsung to gain some non-codified downstream knowledge. On a strategic level, Samsung, with this hire, is trying to minimize the differences in the buyer's journey when buying a Samsung product versus an Apple product.

In April 2018, Apple hired Brandon Yoon, former Chief Digital Officer (Corporate Vice President). At Samsung, Yoon was responsible for digital strategy, E-commerce and business incubation. At Apple, Yoon is hired to lead the Apple business in Korea and strengthen their position in the homeland of Samsung. Worth noting is that his former position at Samsung was also based in Korea. With this hire, Apple is trying to get a stronger hold in the domestic market for Samsung. Yoon has a strong knowledge of the dynamics in the Korean market of consumer electronics. Besides that, he has strong knowledge of consumer preferences and the strategic roadmap at Samsung (Yoon, B., n.d).

In December 2018, Apple hired Soonho Ahn as the global head of battery development. Ahn has a history at Samsung SDI as the Senior VP of batteries, and at Apple, Ahn is hired as Global head of Battery Developments. At Samsung, Anh was the lead in developing lithium batteries and the next generation of batteries (Ahn, S., n.d). Apple has used batteries from Samsung SDI in the past, and this hire can be seen as a strategic attempt to make them more independent from suppliers (Gurman, M., & Kim, S., 2019). Hiring an employee from a specialized company comes with value beyond the hire itself. The knowledge accumulated by Samsung SDI on batteries is beyond the level of what they have internally. Besides having strong knowledge of battery technology, it can also disclose information about the specifications of future Samsung products.

The latest debated transfer is of Kim Woo-Pyeong, leaving Apple in favor of Samsung. Woo-Pyeong is considered a semiconductor expert and was appointed as the Samsung Packaging Solution Center director. Only a little information has been disclosed on which project Woo-

Pyeong will work on. Rumors are that Samsung is focusing on developing new chip packaging to overcome physical constraints (Eun-jin, 2022).

As seen in these examples, the responsibilities are often according to what the employee did at their former workplace. This is a natural cause, as in the job market, one often finds jobs according to prior experiences. However, what is interesting here is that the two companies are in fierce competition, and it gives an insight into the competing company's strengths and weaknesses. As mentioned by Karlssons C. et al. (2012), the mobility of employees with relevant knowledge and skills is a channel of knowledge spillover across and between industries. This mobility proves that knowledge moves both downstream and upstream. However, it is not easy to make conclusions about how this potential spillover is utilized because, for obvious reasons, the new employer will not disclose why and how they will benefit from it. Because of the fierce competition, much speculation is made as these types of transfers get a lot of media attention.

5.Conclusion

The purpose of this paper has been to explore R&D as knowledge spillovers as a concept and see if there is evidence for cross-border spillovers. The literature review reveals a broad consensus theoretical aspect. The taxonomy of spillovers is the same throughout the articles. The distinction between rent spillovers and pure spillover is of great concern in most of the publications. The authors also tend to agree on which channels spillovers can be transferred through. With moderation, they distinguish between three main channels:

1. The pure spillover is non-embodied and happens intentionally/unintentionally.
2. The transaction based.
3. The by-product of a transaction.

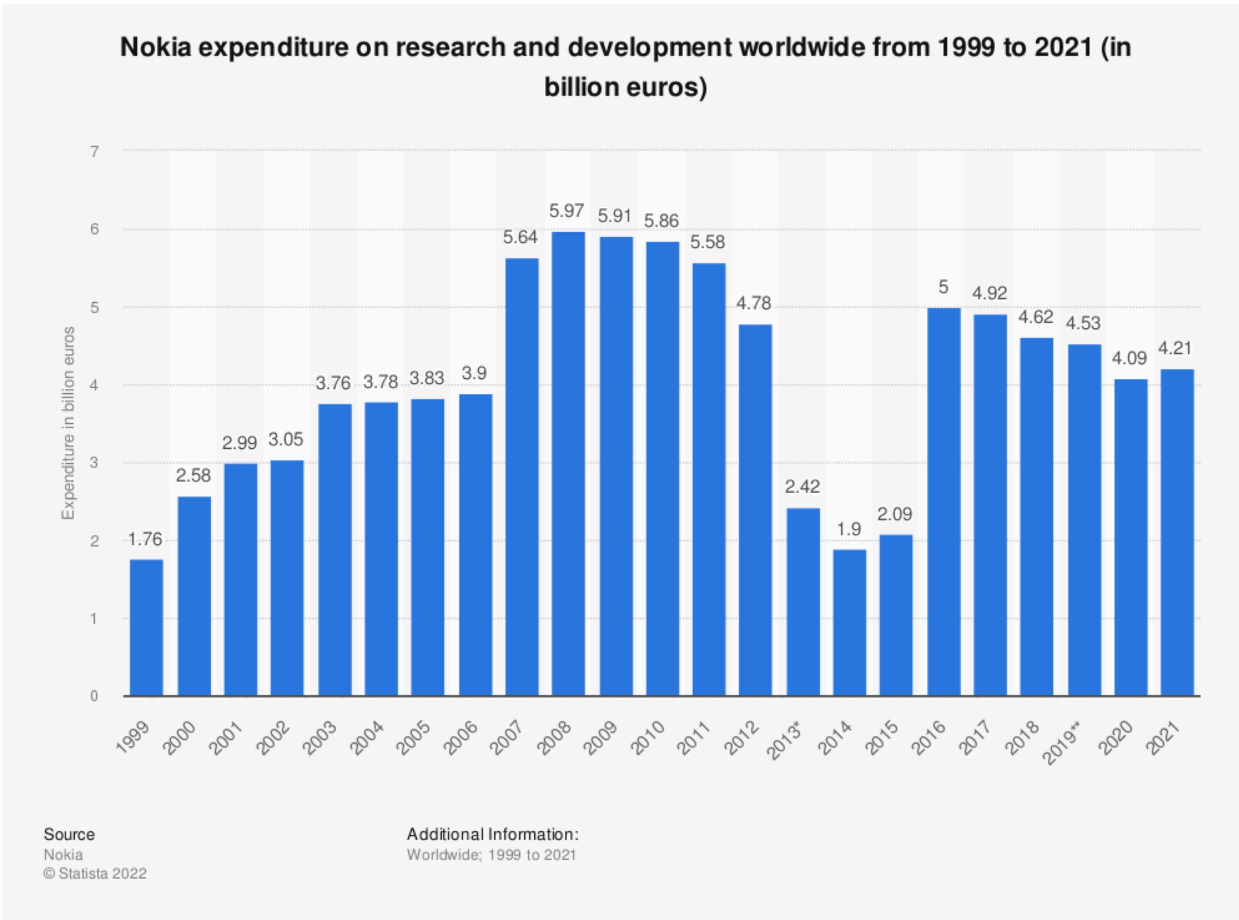
Most of the literature also favors a Cobb-Douglas production function, but there is a reasonable disagreement about which variables are most suitable. Given that the measurement of spillovers is somewhat ambiguous, it makes the literature point in different directions. Besides the varying approaches, the literature agrees that spillovers significantly impact production. However, the literature struggles to find a measure where it is definite that we are only measuring pure spillovers. The issue of isolating pure spillovers from rent spillovers is an issue addressed by several publications.

The Nokia case proves the suggested theory that employee mobility can be channel for spillovers. It is clear to see that hiring an ex-Nokia employee has a significant impact on the company's performances. The variables that experience the biggest impact is the value-added and operating profit. In the light of the Nokia case, they went out of the industry, but this is convincing evidence that competitors can gain a stronger position, if they absorb spillovers.

The Apple-Samsung case is an example of multiple spillovers happening when companies are in fierce competition. The case illustrates how spillovers can happen when companies engage in partnerships and also an example of employee mobility. The spillovers identified is based on theory and secondary data. The case could benefit from a more statistical approach to conclude on the spillovers. As none of the companies is explicitly stating they benefited from spillover it can be difficult to draw a definitive conclusion.

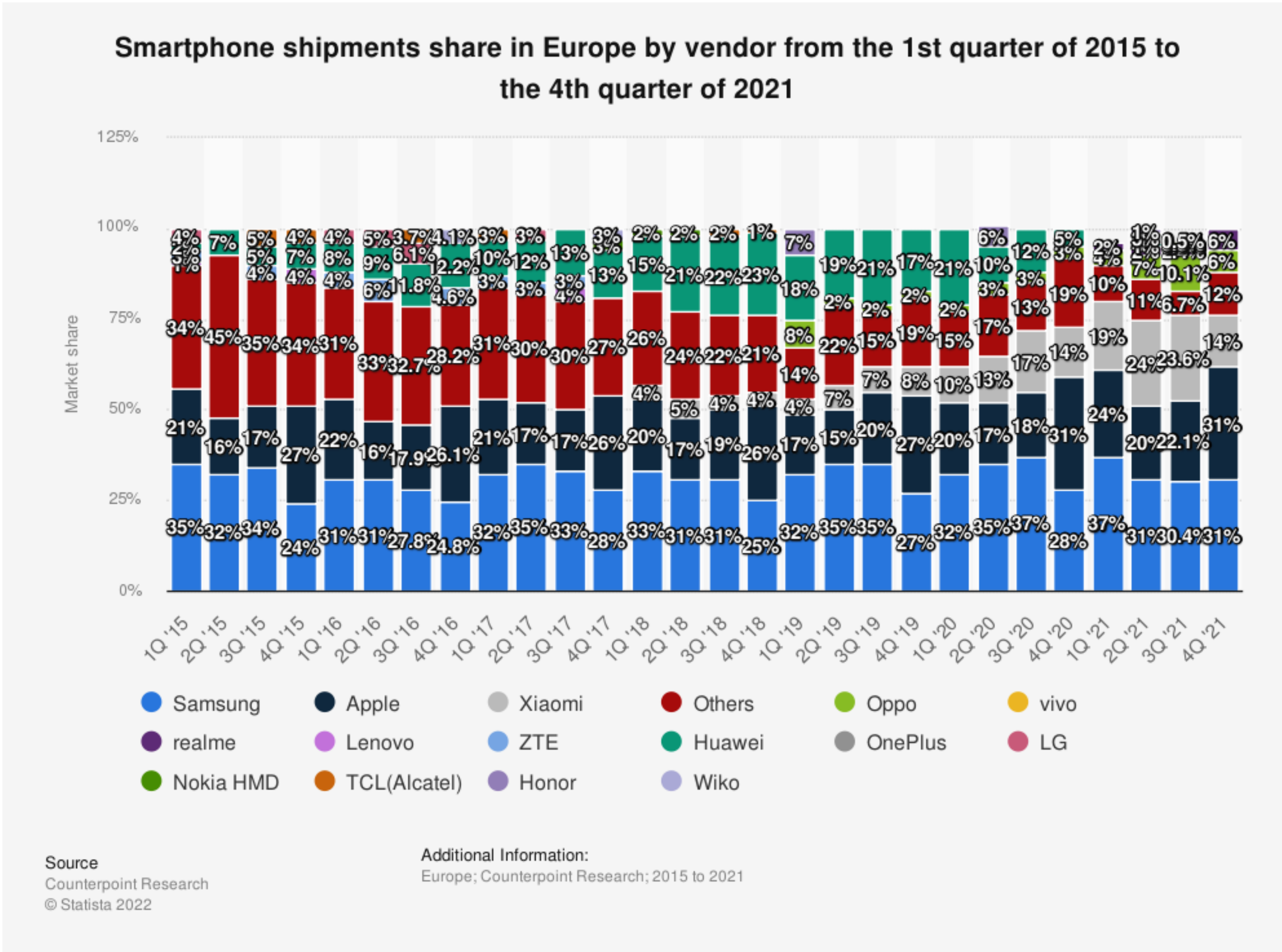
6.Appendices

Appendix 1.



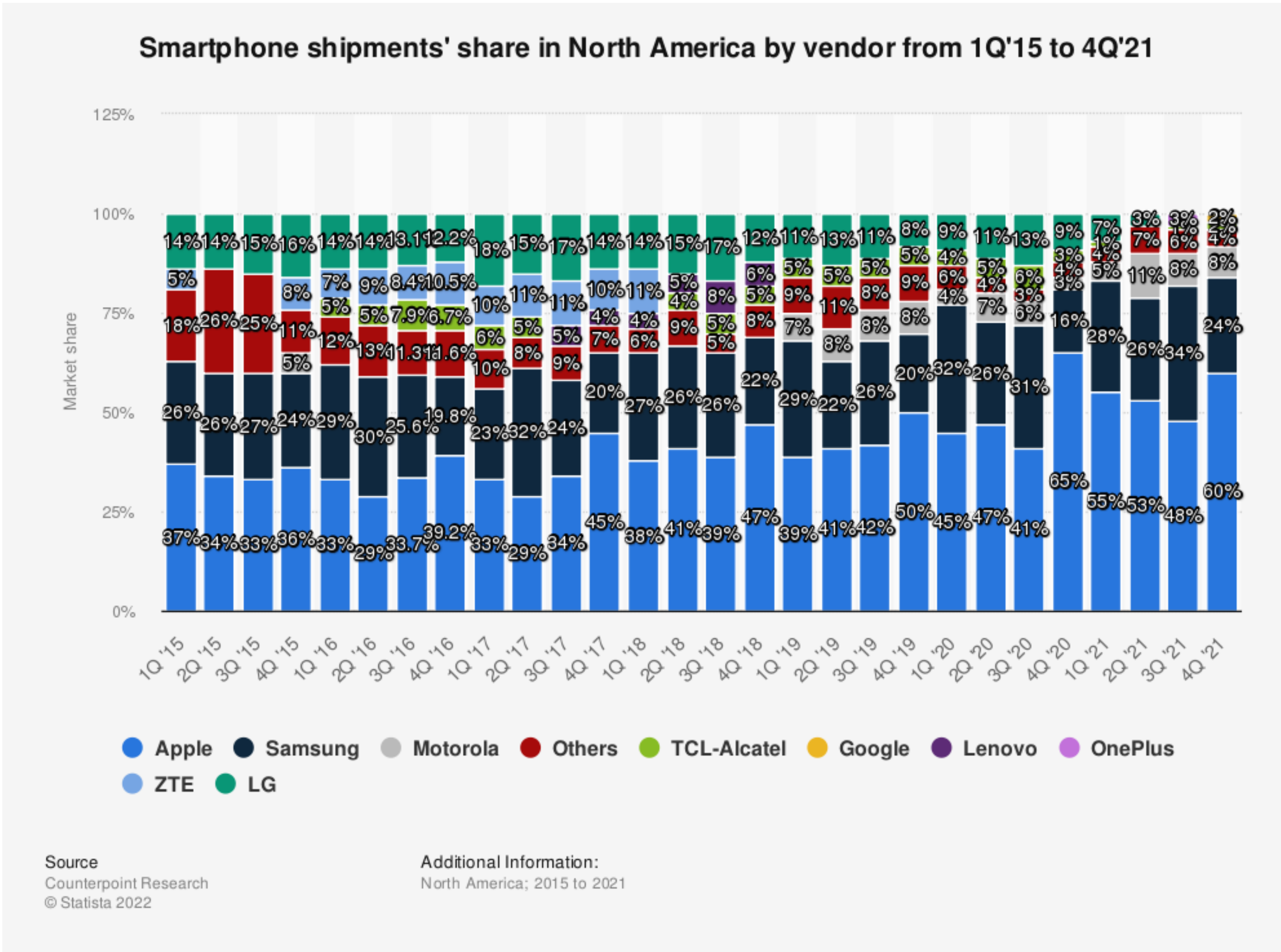
(Source: Statista)
https://www-statista-com.revproxy.escpeurope.eu/statistics/267821/nokias-expenditure-on-research-and-development-since-1999/

Appendix 2.



(Source: Statista)
https://www-statista-com.revproxy.escpeurope.eu/statistics/632599/smartphone-market-share-by-vendor-in-europe/

Appendix 3.



(Source: Statista)
https://www-statista-com.revproxy.escpeurope.eu/statistics/632574/smartphone-market-share-by-vendor-in-north-america/

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