11 JUNE 2014

WHAT HAPPENS WHEN ENTREPRENEURS ACT?

A STUDY ON THE INTERMEDIARY ROLE OF INNOVATION IN THE RELATION BETWEEN ENTREPRENEURSHIP AND ECONOMIC GROWTH

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MASTER THESIS IN ECONOMICS AND BUSINESS
SPECIALIZATION: ENTREPRENEURSHIP & STRATEGY ECONOMICS

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Abstract

It is now generally believed and accepted that entrepreneurship plays a key role in explaining and stimulating economic growth. The question remains however how exactly this relationship takes shape. In the literature, innovation is often suggested as the intermediary link. This thesis is among the first to research this proposition explicitly by modeling the intermediary role of innovation in the relation between entrepreneurship and economic growth. The Knowledge Spillover Theory of Entrepreneurship is employed as the general framework.

For the empirical application a two-equation model is estimated using two-stage fixed effects panel estimation for 17 OECD countries over the period 1981-2011. The first equation models economic output (GDP) with entrepreneurship and innovation output as explanatory variables. The second equation models innovation output using innovation inputs and entrepreneurship as main explanatory variables. The distinction between innovation input and output is a contribution to the literature, allowing to empirically test the concept of the knowledge filter, *i.e.* the barriers to commercialize new knowledge. I provide a theoretical addition by arguing that an additional filter exists, the open society filter, which represents access to the knowledge stock.

Results for the first equation are in line with the literature. I find positive results for labor, physical capital, education and entrepreneurship. This indicates a linear relation between entrepreneurship and economic output. Second, while previous studies use innovative input as an explanatory variable, this thesis finds a positive effect for innovative output. The results suggest evidence for the knowledge filter. Additionally, a U-shaped relation between entrepreneurship and innovative output is found. This suggests that only after a certain level of entrepreneurship (competition) the effect of entrepreneurship for innovation output is positive. I propose that lower rates of entrepreneurship negatively affect innovative output because knowledge investments (incentives) are negatively affected by more competition. Higher entrepreneurship rates however force firms to innovate in order to stay competitive.

In summary, this indicates that entrepreneurship has a different influence on economic output (static efficiency) compared to innovation output (dynamic efficiency).

Key words: Business ownership, economic growth, knowledge spillovers, economic output

"Education is the most powerful weapon which you can use to change the world."

Nelson Mandela

PREFACE

The Master thesis is the crown on your education. It is the last piece of the puzzle of my Master in Economics and Business at Erasmus School of Economics in Rotterdam. The master has provided me an opportunity to deepen my understanding of applied economics and has pushed me to try my best. Writing this thesis has been a great journey which has forced me to use all my skills and knowledge gained over the last years. I am very proud of the result, the thesis in front of you.

I am very grateful for the many people who have made it possible for me to strive for excellence. I have been lucky to meet inspiring people, both students and professors, during the last years. The different professors in the master program have allowed me to make a deep dive into the material and given me a solid basis for the future. I am confident now that I have a well-stocked box with skills and tools which will proof to be essential for my further career.

During my Master, I was in the fortunate position that many of these wonderful people were my colleagues too. They have made it possible for me to work in a stimulating and fun environment. We shared many laughs, small talk and unforgettable Olympic Games moments. I treasure all conversations and fun dinners. I am grateful to you all for letting me be part of your group and providing me with wonderful advice. Brigitte, Gerda, Jolanda, Martijn, Nita, Peter, Philipp, Ramona and all others: thank you. A special thanks to Roy Thurik for providing me with the opportunity to work for the Entrepreneurship group and giving me all freedom and space to fulfill this position. It opened many doors for me and has added an extra dimension to my education.

I was also lucky to write my thesis in combination with an internship at Panteia in Zoetermeer. This provided me with the opportunity to apply the knowledge from my master and further learn about policy research. I have had a wonderful time and have got to know many inspiring people. Nardo, Jan, Caroline, Sander, Arnaud and all others: thank you. I specifically want to mention two people: Jacqueline Snijders and André van Stel. Jacqueline, thank you for taking me in tow, including me in your projects and introducing me to the world of policy research. I enjoyed our 'world' travels and conversations immensely. Second, André, this thesis would not be possible without your help. Your guidance was detailed, inspiring and extremely useful. I enjoyed our discussions and treasure your support. I could not have wished for a better supervisor.

Lastly, I would like to thank my family and friends who have been very important for me. They have been amazing supporters without whom this process would be much tougher. You were an amazing sounding board which was crucial for me. I especially want to thank my parents, Rudi and Jesse who were always there to listen to my thoughts and complaints on writing this thesis. Papa, thank you for being my ghost reader and 'struggling' through all pages. Mama, thank you for your moral support and listening ear. Rudi, thank you for always being interested and helping me to select this Master program. Jesse, I know you are always there for me, supporting me and helping me to find my balance. Thank you for always listening to all my ideas and concerns. It helped me to structure my thoughts and push through. You are all extremely important to me.

I realize that having all these people surrounding me is not self-evident. I consider myself very lucky.

Sanne Blankestijn, 11 May 2014

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1 INTRODUCTION

Recently entrepreneurship has emerged as one of the key factors in explaining economic growth. As a result the focus of public policy has been increasingly drawn to promoting entrepreneurship in order to boost economic growth and prosperity.

Yet not too long ago, in the early postwar era, all focus was on the Capital Economy. Robert Solow (1956) linked both capital and labor to economic growth in his, at the time, pioneering model. While this model let many economists subsequently focus on using these two factors to explain economic growth, technological progress remained unexplained (or as Solow named it *'manna from heaven'*). The residual variation in growth rates, which could not be explained by capital and labor, was attributed to technological change. Capital was perceived as the main driver of economic growth and it was generally believed that capital was most efficiently used in large firms as they were able to exploit economies of scale. During this era *"Small firms and entrepreneurship were viewed as a luxury, perhaps needed by the West to ensure a decentralization of decision making, but in any case obtained only at a cost to efficiency."* (Audretsch, Keilbach & Lehmann, 2006, p. 16).

Later, in the 1980s knowledge became more prominent and slowly different measures of knowledge were introduced in economic models. It was famously included into the macroeconomic growth models by respectively Paul Romer (1986) and Robert Lucas (1988). Technological progress became endogenous in these models of the knowledge economy. Romer proposed knowledge to be an input in the production function which leads to higher marginal productivity. This knowledge production function model was supported by a large amount of empirical evidence. The evidence showed support for the idea of Zvi Griliches (1979) that in order to create innovations, investments by the firm in knowledge inputs were required. As a result, policymakers soon realized the importance of knowledge to boost prosperity. In subsequent years additional policy measures followed which focused on investments in new knowledge in order to boost, among others, employment and the competitive positions of the respective countries (Audretsch *et al.*, 2006).

Even though knowledge was by the end of the eighties an accepted production factor, entrepreneurship still did not have a substantial role in the public debate. Because of the general feeling that the more one would invest in innovation inputs, the higher the economic growth would be, small firms were still disadvantaged. They had fewer resources than their larger counterparts. They were not able to allocate the resources necessary for the large investments essential to generate knowledge and they could not benefit from scale economies in Research and Development (R&D) by means of R&D laboratories. Several studies found that, when measuring R&D expenses, small firms only accounted for a small fraction of the total innovative activity (*e.g.* Acs & Audretsch, 1990). The general expectation was therefore that, with the revolution of ICT and increased globalization, small firms would diminish even further (Thurik, Audretsch & Stam, 2013; Audretsch *et al.,* 2006).

Starting in the early 90s, scholars began to provide empirical evidence that showed the increase in the number of small firms from the 70s onwards across most developed countries. One example is the study by EIM (2002) which documented the increase of the share of small firms in total employment for 19 countries in Europe. Another example was the increase of new businesses incorporations in the United States with 87 percent between 1976 and 1986, compared with a 39% increase in GDP (Brock & Evans, 1989). The empirical evidence found subsequently raised questions among scholars and they started looking for plausible interpretations and for a theoretical basis of this reemergence. Brock and Evans (1989) were among the first to provide some explanations.[1] For instance the revival of small firms could be viewed as a result of globalization (more volatile markets requiring flexibility), a result of technological change (scale economies decreased in importance due to the ICT revolution) or as a result of a changing structure of the labor force.[2] More women, immigrants,

[1] For a short summary, see Audretsch *et al.*, 2006, page 26.
[2] For a more in-depth discussion of the history of economic growth models and the shift towards an economy with increased importance of entrepreneurship, please see Audretsch *et al.,* 2006 or Thurik *et al.,* 2013.

younger and older people entered the labor market. Due to a greater premium placed on flexible hours and flexibility in general, these groups might be attracted to smaller firms compared to larger firms. Small firms are generally more flexible.

Nowadays we agree that small firms did not become obsolete, in fact we see a very important role carved out for entrepreneurs in the current economy. Small firms have a new role now because the source of comparative advantages has shifted towards a basis in knowledge instead of labor and capital (Audretsch & Thurik, 2001). It is now generally believed and accepted that entrepreneurship plays a key role in explaining and stimulating economic growth. Or, as Romano Prodi stated at the proclamation of the Lisbon 2020 strategy:

> ***"Our lacunae in the field of entrepreneurship need to be taken seriously because there is mounting evidence that the key to economic growth and productivity improvements lies in the entrepreneurial capacity of an economy" (Prodi, 2002; p. 1)***

Prodi, then president of the European Commission also made his remarks in the context of the so-called European paradox. This is the notion that Europe is a leader in terms of scientific output but is lagging in its ability to commercialize this knowledge (European Commission, 1995). Or, in other words, Europe has big difficulties in converting the large amount of new knowledge into wealth-generating innovations. Audretsch *et al.* (2006) and Acs, Audretsch, Braunerhjelm & Carlsson (2004) explained this paradox by the existence of a knowledge filter: the existence of a barrier for knowledge to turn into commercialization. They proclaimed entrepreneurship to be the force which could bring this barrier down. Thus, entrepreneurship was brought up as an important solution in solving this paradox.

The question remains however why the shift towards knowledge should also entail a new and larger role for entrepreneurship. One conjecture has to do with the uncertain nature of knowledge which entrepreneurs are potentially better equipped to handle compared to large firms (Thurik, 2009). Likewise, discussion remains how entrepreneurship influences economic growth. An idea offered by, among others, Audretsch (2009) of entrepreneurship being a conduit for knowledge towards innovation is one possibility. He views entrepreneurship as the missing link which turns knowledge into *economically valuable* knowledge. Yet, we still do not have a comprehensive understanding of how the variables knowledge, innovation and entrepreneurship would interact. Some literature also pleads for different intermediate linkages between entrepreneurship and growth (*e.g.* Carree & Thurik, 2006; Audretsch & Thurik 2004; Friis, Karllson & Paulsson, 2006). Examples of these linkages may be innovation, competition, diversity or new entry. Typically these intermediate linkages are not explicitly modeled in empirical models linking entrepreneurship and economic growth and therefore their influence is not yet determined.

In particular the theoretical distinction between knowledge and economically valuable knowledge[3] is normally lacking in empirical growth models. That is, knowledge in growth models is typically measured in R&D (for example, the amounts spent on R&D or the number of researchers in a country). R&D is however an input factor for innovation which does not provide information on the innovation output. They are correlated with each other but should not be considered the same.[4] Also R&D is neither necessary nor a sufficient requirement for innovation because it excludes inventions made by individuals who have a non-R&D job. To illustrate this distinction, Carlsson & Fridh (2002) found that only half of the disclosed inventions of United States universities actually resulted in patent applications. Of these applications, only around 50% is actually assigned. Taking this one step further, about 1/3 of these patents is licensed. Not all licenses yield income, only 10-20% yields a

[3] See Acs *et al.* (2004).
[4] For example, Acs & Audretsch (1990) find a correlation of 0.74 between R&D and innovation output at the level of industries (four-digit sic).

considerable income. Short and good, only 1-2% of the inventions of these universities can be considered a success. This example illustrates the importance of attention for the connection between inventions and economic growth. Only those inventions which are able to constitute to a commercial opportunity will grow the economy. Thus, *economically valuable* knowledge or innovative output is what is ultimately influencing economic growth (Arrow, 1962a; Romer, 1986; Acs *et al.*, 2004; Mueller, 2006). This crucial link is important in the explanation of how knowledge spillovers, a key element in endogenous growth theory, can occur. This step between knowledge and economically valuable knowledge is typically not modeled.

In this thesis the distinction between innovation input and innovation output is explicitly modeled. By estimating a model in which innovation output serves as the dependent variable and innovation inputs as the independent variables, this thesis provides insight in this evolutionary process. Second, by adding a second equation and estimating both in a simultaneous equation model, insight is provided in the link between innovation inputs, innovation outputs and economic growth. I model innovation outputs as intermediate linkage between innovation inputs and entrepreneurship on the one hand and economic growth on the other hand. Except for this indirect link between entrepreneurship and economic growth, I also consider the potential direct influence of entrepreneurship on economic growth, for example by increasing the competition. Providing this new and extensive empirical application provides a novel and crucial insight in the different roles that entrepreneurs play in the economy. It thereby helps to achieve the aim of this paper, namely to explicitly model the intermediary role of innovation in the relation between entrepreneurship and economic growth.

Using the Knowledge Spillover Theory of Entrepreneurship of Acs, Braunerhjelm, Audretsch & Carlsson (2009) as a starting point, I develop an empirical framework. First, I found a confirmation of the general economic growth models which indicates that capital and labor are important drivers of economic growth. Second, I found that innovation, measured as knowledge output, influences growth in a positive way as well. Evidence was also found for the direct and indirect effect of entrepreneurship. Entrepreneurship has a direct and positive influence on economic growth. The effect on innovation is U-shaped indicating that the indirect influence of entrepreneurship is positive when a certain threshold level of entrepreneurial activity is achieved.

This paper is structured as follows. First, entrepreneurship is a notion with many different facets and aspects. Section two will therefore provide a short summary of the different types of entrepreneurship and then describe what is understood as entrepreneurship in this paper. Section three will focus on innovation and its relationship with economic growth and with entrepreneurship. Section four will deduct the research question and provide hypotheses. Section five elaborates on the data and methodology. Furthermore, section six will present the results and discussion while section seven concludes.

2 ENTREPRENEURSHIP

2.1 THE NOTION OF "ENTREPRENEURSHIP"

Before linking entrepreneurship to economic growth, it is crucial to define the term. This section will build upon the historical views of entrepreneurship and other literature to describe which type of entrepreneurship might lead to economic growth. As will become clear in the rest of this section, the focus will be on a special kind of entrepreneurship, namely the innovative type. This section will provide the characterization of entrepreneurship used in the rest of this paper. It specifically focuses on the economic aspects of the term. Beyond the scope of this section are other facets, such as psychological or sociological characteristics of entrepreneurs.

The section is structured as follows: first the occupational and behavioral views of entrepreneurship are introduced. This section forms a starting point in defining the term entrepreneurship. From this subsection I decide to focus on the behavioral notion because of the focus in this paper on the role the entrepreneur plays for economic growth. The second subsection thus provides a larger introduction in this topic. I then explain some historical views and current views on entrepreneurship in order to come to a workable definition for the remainder of this thesis. Finally, in two separate subsections I discuss how two often used concepts in entrepreneurship literature relate to my theoretical definition of entrepreneurship. The first definition is small business, while the second is the distinction between opportunity and necessity entrepreneurship. These subsections are important in order to provide a complete view of the entrepreneurship literature. The section concludes with a wrap-up.

2.1.1 OCCUPATIONAL VIEW AND THE BEHAVIORAL VIEW

When answering the question about what entrepreneurs do, Sternberg & Wennekers (2005) introduce two distinct dimensions. These perspectives are known as the occupational notion and the behavioral notion. It resembles a distinction made earlier by William Baumol (1993, p. 198). He makes a contradiction between the 'firm-organizing entrepreneur' of Cantillon and the 'innovating entrepreneur' of Schumpeter.[5] The occupational choice notion focuses on the labor market position of the entrepreneur. In this notion, the entrepreneur is an individual who manages and owns an enterprise for his own account and risk. The notion thus makes the distinction between self-employment and wage-workers. It has both a dynamic and a static perspective: focus on the creation of new enterprises or the number of business owners in the economy (Wennekers, 2006). The behavioral notion focuses on the behavior of the entrepreneur in how he seizes economic opportunities (Sternberg & Wennekers, 2005).

Davidsson (2004) does not explicitly talk about these notions, but uses the term 'social realities' in his quest to a definition of the concept of entrepreneurship. He states that the different entrepreneurship definitions are a reflection of these social phenomena. The first reality is the idea that some people rather work in self-employment than in an employment contract. They might have some innovation at start-up and they will possibly have some degree of innovativeness over time in order to survive. However, most businesses are relatively stable and operate in relatively stable industries. Here, the idea of self-employment is crucial and the reality is focused on aspects as small business management or stages-of-development models. This first reality is thus similar to the occupational notion, focusing on entrepreneurship in a definition as *"anything that concerns independently owned (and often small) firms and their owner-managers"* (Davidsson, 2004, p. 4).

The second social reality is closer to the behavioral notion. Innovation is crucial in the second reality which emerges from the important theme of development and renewal of the economy. It is embedded in the idea that we need actors of change, entrepreneurs, to help develop the economy further. Institutions or market structures play a role, put they do not create the change themselves. The entrepreneur has to be persistent and take the initiative to continue further. It is only in this second reality that topics as Schumpeterian

[5] See also the next subsection on macro-perspective views of the behavioral notion.

entrepreneurship or corporate entrepreneurship become meaningful (Davidsson, 2004). Hence, in this social reality more attention is paid to topics on dealing with potential opportunities.
Although these social dimensions are partly overlapping, the distinction between occupational and the behavioral notion are clearly resembled.

To summarize the behavioral and occupational notion, the following table provides an overview:

	Self-employed	Employee
Entrepreneurial	Independent entrepreneurs	Corporate entrepreneurs
Managerial	(Managerial) business owners	Executive managers

TABLE 1: THREE TYPES OF ENTREPRENEURSHIP VERSUS EXECUTIVE MANAGERS (SOURCE: WENNEKERS, 2006, P. 28)

This table uses the distinction in the occupational sense (self-employed versus employee) and the more behavioral notion (entrepreneurial versus managerial). Three types of entrepreneurs are presented in the table against one type of manager. The main focus in the entrepreneurial definition is on the opportunities. This means that you look at how entrepreneurs find these opportunities and what they do with them. When the main focus is on decision-making for resources you are more talking about 'management' instead of entrepreneurship. From the table it also immediately becomes clear that entrepreneurs do not necessarily have to be business owners.

In this thesis the focus is on the entrepreneurial type: the type of behavior which concentrates on the perception, exploitation and creation of new economic opportunities (Wennekers & Thurik, 1999). I thus take the behavioral view as a starting point for my analysis, with a focus on the role entrepreneurs play for economic growth. Looking at entrepreneurship in the behavioral sense, terms as 'innovators' and 'pioneer' can be considered synonyms (Sternberg & Wennekers, 2005).

2.1.2 Entrepreneurship in a behavioral sense

When talking about entrepreneurship in the behavioral sense, one can take both the macro- and micro-perspective on the role that entrepreneurs play. This macro-perspective focuses on the role that entrepreneurs play in the economy as a whole. The micro-perspective on the other hand focuses on the level of the individual and tries to explain the behavior and proceedings of entrepreneurs themselves. For the macro-perspective, some historic views of entrepreneurship are of interest. These views can be categorized in three schools or mindsets, which will be discussed first. Second, when focusing more on the micro-definition, recent views of entrepreneurship become more important. We will discuss these definitions and choose one as a starting point for the remainder of this thesis.

2.1.2.1 Historical views on entrepreneurship (macro-definitions)[6]

This historical views section focuses on the role of entrepreneurship as a production factor, besides labor, land and capital. I look at entrepreneurship from a theoretical perspective and on the macro-level. Here, entrepreneurship is about the effect of the actions of the entrepreneur on the general economic system. Given that the focus of this paper is on economic growth, one should look at the entrepreneur with a dynamic outlook. Only in a dynamic world change and uncertainty occur, and this is where the entrepreneur will play a significant role. The entrepreneur can then be viewed as someone who is more the owner of an enterprise or who is more than a manager (Hébert & Link, 1989). The first to provide a definition and introduce the term 'entrepreneur' was Richard Cantillon, back in 1755, who was also the first to give the entrepreneur a specific function in the economy. Cantillon's entrepreneur is someone who engages in market transactions while facing uncertainty. He is the bearer of risk (Cantillon, 1931).

[6] The main source for this section is the classical work by Hébert and Link (1989) who discuss the history of the term entrepreneurship and the different roles of the entrepreneur.

Three main ideas or traditions can be distinguished, all with their origins in Cantillon's views: the German, the (neo-) classical (or Chicago) and the Austrian tradition (Hébert & Link, 1989). The most prominent representative of the German tradition is Joseph Schumpeter; Frank Knight as well as Thomas Schultz are most famous for the (neo-classical) tradition while Israel Kirzner is well known as representative of the Austrian school (Wennekers & Thurik, 1999). These traditions all emphasize a different role of the entrepreneur. The table below provides an overview of the three roles; a further illustration follows in the text below:

Role	Economist
Innovator	Schumpeter
Perceiving profit opportunities	Kirzner
Assuming risks associated with uncertainty	Knight
Restore equilibrium	Schultz

TABLE 2: ROLE OF THE ENTREPRENEUR

The introduction of a new product or new enterprise can be viewed as an entrepreneurial act with respect to all roles. Someone innovates by introducing something new, by seeing an opportunity in the market for the new product and he finally takes the risk that the introduction might fail. All traditions believe in a different function in the economy which is fulfilled by the entrepreneur. So not every act perceived as entrepreneurship by one tradition is automatically entrepreneurship in the eyes of others.

The German tradition believes in the entrepreneur as a cause of '*creative destruction*' and consequent instability. Creative destruction is a term defined and developed by Schumpeter who describes it as follows (1942, p. 83, his emphasis):[7]

> ***"The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, ... [This process] incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism."***

Creative destruction is thus the process triggered by the entrepreneur. He destroys the current economic order (routines, systems) by introducing innovations. This innovative entry sustains economic growth. Schumpeter thus sees the entrepreneur as the supplier of change (Schumpeter, 1942). By introducing these new products, techniques or otherwise, the entrepreneur causes the economy to move further from equilibrium. This process of creative destruction is the key term in the so-called Schumpeter Mark I regime (Schumpeter, 1934).

The (neo-) classical school on the other hand, considers the entrepreneur as someone who leads the market to its equilibrium state. The equilibrium is thus the starting point of the reasoning. Entrepreneurs fit in the neo-classical framework by coordinating supply and demand, capital and labor and the production and distribution process. The entrepreneur is able to distinguish between risk and uncertainty. Risk has the advantage that it can be calculated opposite to uncertainty for which the probabilities are unknown (Knight, 1921). Knight suggests that the entrepreneur changes uncertainty in options with known risks. The key element of the entrepreneur's position in a corporation (enterprise) is his responsibility in cases of uncertainty to bring direction and control. This added an additional dimension to Schumpeter's view, namely that also the cognitive abilities were introduced as an explanation for entrepreneurial activity. Knight's key contribution was the insight that if someone decides to be an entrepreneur or an employee, this decision depends on the risk-adjusted reward in the sector.

[7] The combination of these quotes is provided by Aghion & Howitt (1992).

Schultz (1975) also belonged to the neo-classical tradition because he believed in the ability of entrepreneurship to restore equilibrium (Wennekers & Thurik, 1999). He has advanced the concept of entrepreneurship in two major ways. His starting point was the theory of human capital. Schultz believed that entrepreneurship could be viewed as *'the ability to deal with disequilibria'* (Hébert & Link, 1989, p. 45). This is not only limited to markets, but also standard decisions, for instance within your household. Second, he provided evidence that education has an effect on one's ability to deal with these equilibria. Schultz believed that entrepreneurial ability has its own marginal product, therefore making it a useful factor of production. Because entrepreneurship is a useful factor of production, a market should be in place for it. The price for entrepreneurship at that market is according to Schultz dependent on a differentiated return to ability (Hébert & Link, 1989).

Finally, the Austrian school argues that the entrepreneur works towards restoring the equilibrium, in most cases after an exogenous shock. The difference with the neo-classical school is large: neo-classical economists analyze a world in equilibrium. Economists from the Austrian school on the other hand view it as highly improbable that the economy is indeed in equilibrium or close to it. They actually look at the process of economies shifting towards the equilibrium and the potential role entrepreneurs could play (Van Praag, 1999). So, the opinion about equilibrium is a factor differentiating both traditions. The entrepreneurs in the Austrian view try to fulfill existing needs or improve the market faults. Kirzner (1973) looks at the entrepreneur as someone with the skill to analyze and identify profit opportunities. The essence is thus in how alert one is to see these possibilities. These profit opportunities consequently lead to companies of entrepreneurs entering the market. By doing so, supply rises and prices fall until the moment that nobody makes a profit. By entering, the entrepreneur systematically pushes the market towards its equilibrium state (Kirzner, 1973). Thus, for Kirzner, the role of the entrepreneur is to make sure that the adjustment necessary to move markets to their equilibrium state is achieved. This equilibrium however is never reached due to opportunities that are missed and judgmental mistakes. In his view, "[…] *entrepreneurship is inherent in the competitive market process*" (Kirzner, 1973, p. 17). Given this broad definition, one could say that in Kirzner's eyes anyone who runs a (successful) business is an entrepreneur. Leibenstein (1968) takes Kirzner's approach even one step further, viewing entrepreneurs as people who see the inefficiencies in a market and destruct them.

Combining the views set-out above, I deduct that Schumpeterian and Kirznerian entrepreneurship can be viewed as complementary. In the sense that the disequilibrium generated by the Schumpeterian entrepreneur offers a gap for the Kirznerian entrepreneur to jump into upon identifying the situation as an opportunity (Kirzner, 1999). This occasion should then be an opportunity which brings the economy to a higher-level equilibrium and thus contributes to economic growth. The opportunity is created by the Schumpeterian entrepreneur who has made the disruption in the first place. Others, like Holcombe (1998) for example, feel that there is no difference in the activities of Kirznerian or Schumpeterian entrepreneurs. They all alter the subsequent outcome for the markets. When strictly following Kirzner's definition, the assumption should be that once the market reaches its equilibrium, the entrepreneur will lose its role as producer of growth. Without the opportunities which the Schumpeterian entrepreneur generates, entrepreneurs have an obsolete role. In the long run economic growth is determined by Schumpeterian entrepreneurship. Therefore in the remainder of this paper I look at the role of entrepreneurship in the economy through Schumpeterian glasses.

2.1.2.2 Recent views (micro-level)

More recently, the notion of entrepreneurship is still up for debate. On the micro-level however, the views of Schumpeter remain current and important. His notion of the entrepreneur can also be applied on the micro-level of the behavior of the individual entrepreneur. He identifies five ways in which entrepreneurship can present itself, namely by the introduction of new goods, new production methods, new markets, a new organization or a new source of supply of intermediate goods (Schumpeter, 1934). The entrepreneur himself is an innovator, a person with entrepreneurial traits. He behaves as an entrepreneur by making the new introductions. He can demonstrate those in a small firm but also in large firms, but his behavior remains key.

More recently, however, multiple definitions have been proposed, mostly based on a synthesis of the existing (theoretical) literature. Examples consist of Hébert and Link (1989) who list twelve different concepts of entrepreneurship.

At one time or another, these concepts have all been ideas from economists on the definition of entrepreneurship. They also come to a synthetic definition which reads as follows (Hébert & Link 1989, p. 47): *"The entrepreneur is someone who specializes in taking responsibility for and making judgmental decisions that affect the location, form, and the use of goods, resources, or institutions."* This definition does not provide enough tools to connect with economic growth because it does leave out the aspect of working with economic opportunities as well as competition. A definition which incorporates entrepreneurship and economic growth needs more attention on the creation and perception of these opportunities (Wennekers & Thurik, 1999).

Another stream of literature, the strategic management literature, focuses on the behavioral notions as introduced above. Others have focused on *'new venture creation'* as the topic of entrepreneurship (for example Cooper, 2003; Stevenson & Jarillo, 1990). Lumpkin & Dess (1996) distinguish between two aspects: entrepreneurship and entrepreneurial orientation. They define entrepreneurship as *new entry*. It explains what entrepreneurship consists of while they use the term entrepreneurial orientation for the process which leads towards the new entry. This involves the decision-making and practices that lead to the entry of new businesses. Carree & Thurik (2006) give the example of entrepreneurship defined as behavior focusing on the selection of opportunities. Casson (2003) focuses on the entrepreneur as a decision maker.

Wennekers & Thurik (1999) focus on the behavioral notion. Their article is specifically aimed at combining different strands of literature in order to make the connection between entrepreneurship and economic growth. They discuss different views on entrepreneurship and deduct that entrepreneurship may be a mix of two things: *'decision-making on the location, form and use of resources'* and *'the creation and perception of new economic opportunities'.* Studying the potential relationship between economic growth and entrepreneurship forms a basis for their definition. Their definition reads as follows (Wennekers & Thurik, p. 46):

"Entrepreneurship is the manifest ability and willingness of individuals, on their own, in teams, within and outside existing organizations, to:

- ***Perceive and create new economic opportunities (new products, new production methods, new organizational schemes and new product market combinations) and to***
- ***Introduce their ideas in the market, in the face of uncertainty and other obstacles, by making decisions on location, form and the use of resources and institutions."***

Their eclectic definition of the entrepreneur can be linked to all three traditions mentioned above: the perception of opportunities, facing risks by introducing goods to the market and innovative introductions. Wennekers & Thurik (1999) conclude that entrepreneurship is more a behavioral notion, which fits in my shift of focus towards the micro-level of the economy. As their definition is so closely connected to my goal, that is, it is not limited to small firms and that it provides all necessary clues for the remainder of this paper, I have selected this description of entrepreneurship as the definition for the remainder of this thesis.

Application of the behavioral notion can be done on both individuals as well as on to corporations, while the occupational notion can only be applied to individuals. As was shown in table 1, entrepreneurs can both work in existing firms or be self-employed. One example of recent progress in the literature is the increase in attention towards the person of the entrepreneur who is working in an existing firm. This is often defined as 'corporate entrepreneurship' (Stevenson & Jarillo, 1990). The focus is still on the person of the entrepreneur and his behavior is leading here. Corporate entrepreneurship is the process where from within an already existing company, a new idea is launched distinct from the parent company. It does however often use the resources, knowledge and capabilities of the parent firm (Wolcott & Lippitz, 2007). This is thus a spin-off, where a new firm is launched. For example, current employees from one firm can start a new one together. Another possibility is a company creating a separate entity for one of their products. In the current economy, this entrepreneurial mindset is something large firms are also looking for but it is executed in different ways (Lerner, 2012). It is therefore that the strategy literature sees three types of corporate entrepreneurship, as demonstrated in the following table:

Types of Corporate Entrepreneurship	Description
Corporate venturing (intrapreneurship)	Creation of a new business within the existing organization. This means diversification through internal development (Burgelman, 1983)
Renewal corporate entrepreneurship	Activity associated with transformation/renewal of existing businesses
Schumpeterian corporate entrepreneurship	Enterprise changes the competition within the industry by innovation

TABLE 3: TYPES OF CORPORATE ENTREPRENEURSHIP (SOURCE: STOPFORD & BADEN-FULLER, 1994, P. 521-522)

This table describes three types of results of corporate entrepreneurship. Thus, these are the consequences of the newly launched firm (spin-off). One of these types is denoted as Schumpeterian based on the consequences for the industry. This is when the enterprise changes the rules of competition for the industry in the sense of creative destruction (Stopford & Baden-Fuller, 1994). Wennekers & Thurik (1999) find that the initiative taken by the incumbent only becomes entrepreneurial in the Schumpeterian sense when a spin-off is realized. They thus take a stricter approach for qualification by demanding this form.

2.1.3 Entrepreneurship and small firms

Given the definition which we have discussed above, there is a need to discuss how small firms fit in the given definition. The common view that entrepreneurship is a synonym for small firms is a misperception. It is the general opinion in academics that entrepreneurship does not always coincide with small firms (*e.g.* Van Praag & Versloot, 2007; Carree & Thurik, 2006). The concept is broader and captures a wider spectrum of opportunities and notions. As Wennekers & Thurik (1999, p. 29) state *"Small firms certainly are a vehicle in which entrepreneurship thrives. There are more such vehicles, for instance business units within large companies"*. Entrepreneurial activity[8] can take place in small firms where innovations are created and brought to the market but it can also be viewed as the creation of new (small) firms (Lumpkin & Dess, 1996). Then again, being a small firm does not guarantee innovative solutions which contribute to economic growth. There are also plenty of small firms where the owner owns the business to acquire a nice living without the true entrepreneurial motives implied here (Wennekers & Thurik, 1999). Examples of the latter category might be shopkeepers or holders of franchises. Entrepreneurial activity can thus occur in small firms, large businesses or even in government. It is a behavioral notion more based on the way one acts than on the start-up of a business. Empirical evidence supports the view that entrepreneurship adds to growth in more ways than just through small firms. Cohen & Klepper (1996) support this in their study on the nature of innovation and so does Nickell (1996) with his study on the role of competition.

In this section, entrepreneurship has been described as a multidimensional term. I looked at entrepreneurship as a behavioral notion, not a concept only related to firm size. It was proposed that both entrepreneurs in small firms as well as employees with an entrepreneurial mindset in large firms co-exist and some of them can be viewed as Schumpeterian entrepreneurs. In order to be a Schumpeterian entrepreneur, they should be innovative and create the appropriate change. It is more about what is done than who does it in a certain type

[8] Defined by the OECD as *"The enterprising human action in pursuit of the generation of value, through the creation or expansion of economic activity, by identifying and exploiting new products, processes or markets."* (See Ahmad & Seymour, 2008 in their OECD report).

of organization. This is shown in the following picture. Especially of interest are the overlaps between both Schumpeterian entrepreneurship and small firms and between Schumpeterian entrepreneurship and corporate entrepreneurship. These are the areas on which I focus in this paper. Thus, when the individual actor in the small business acts like an entrepreneur, the definition coincides. This however does not have to be the case.

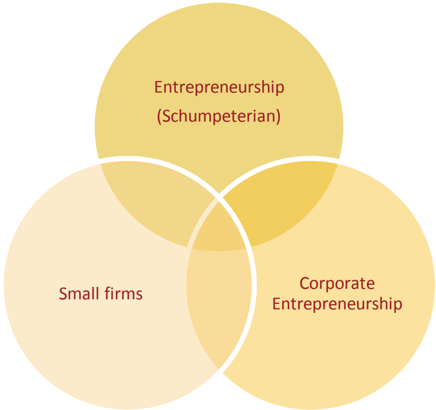

FIGURE 1: ENTREPRENEURSHIP, SMALL FIRMS & CORPORATE ENTREPRENEURSHIP

2.1.4 Opportunity and necessity motives & requirements for entrepreneurship

A few additional topics need to be discussed here in order to complete this chapter. First, I discuss some requirements for opportunities for entrepreneurs to exist. These opportunities are necessary for the entrepreneur to be able to show his potential for economic growth. Second, a limited discussion is provided on two different types of motives from entrepreneurs. The distinction between necessity and opportunity motives is made multiple times in the literature and may influence the entrepreneurial impact.

When one views, as I did above, the entrepreneur as a starter of new economic activity, several conditions are necessary in order for entrepreneurial opportunities to be seized (materialized) (Stam, 2008; Shane, 2004, p. 6):

1. Existence of entrepreneurial opportunities. Shane (2004) refers to changes in the external environment. For instance in the field of technology, regulations or the demographic structure of a country.
2. Diversity in people: not all people should act on opportunities but there should be a difference in the willingness and ability to pursue the opportunities.
3. Risk bearing: only after the entrepreneur chased the opportunity should uncertainty diminish or disappear. Shane (2004) refers to questions about demand or competition.
4. Organizing: how is the entrepreneur pursuing the opportunity? Options are starting a new firm, creating a spin-off or for instance licensing. One should select the appropriate type of organization to seize the opportunity.
5. Innovation: making new combinations of resources to improve or develop a new product and/or service. Here a change is necessary, so no imitation.

The last condition is especially applicable when focusing on innovative entrepreneurship as we do here.

One other topic should be discussed here: the distinction between necessity and opportunity entrepreneurship. In line with Kirzner, opportunity entrepreneurs make an active choice to become an entrepreneur. They see an opportunity in the market and start their new enterprise to fill this void. Necessity entrepreneurs do not see another possibility to earn a living then to become entrepreneurs; there are ‘no better choices’ (Reynolds *et al.*, 2002). In the literature a connection is often made with push- and pull factors. Pull factors are positive, like the wish for personal achievements or independence. Push factors are negative, for instance unemployment or pressure of the family to start the business (Reynolds *et al.*, 2001).

According to Acs (2006), the difference between both types of entrepreneurship is important when studying economic growth. He finds that the impact of opportunity entrepreneurship is positive and significant while necessity entrepreneurship has no effect on economic development. This result is duplicated by Acs & Varga (2005) in a study with eleven countries in the sample. Opportunity entrepreneurship is often related to innovative entrepreneurship while necessity entrepreneurship is usually related with the less innovative kind. Following Acs's (2006) argumentation, one might say that pushing into entrepreneurship leads to underdevelopment by the entrepreneur. If the only reason is that you are not satisfied with other work options, the motivation to let your firm grow and develop might be lacking. In contrast, some people might need the push to reach their full potential. The start-up motivation might thus lead to different business performance. Hessels, Van Gelderen & Thurik (2008) provide empirical evidence for the statement that different motivations may yield different performances. They find for example that entrepreneurs with an increase-wealth motive have a higher aspiration for a high growth rate. A different option is that the unemployed who are pushed into entrepreneurship have fewer competencies to run the actual firm, partly due to their lower human capital and hence again results in underdeveloped entrepreneurs (Van Stel & Storey, 2004). Wennekers, Van Stel, Thurik & Reynolds (2005) also find that necessity and opportunity entrepreneurs have a different relation with economic development. They measure economic development by an index for innovative capacity. They find that the relationship between opportunity entrepreneurship and innovative capacity is quadratic (U-shaped) while the relationship between necessity entrepreneurship and innovative capacity is a decreasing L-shape.

2.1.5 Wrap-up

First, we contradicted the occupational and behavioral view of entrepreneurship. I looked at historic views where the role of entrepreneurs in the whole economy was described, leading to the selection of the Schumpeterian entrepreneur, sometimes in overlap with the corporate entrepreneur, as the preferred definition when discussing economic growth. The discussion was based on the macro-level, focusing on the role which entrepreneurs play to clear markets[9]. In this subsection I focused on the behavior of the individual entrepreneur. It was shown that the entrepreneur is a key player – especially in Schumpeter's economic world – because the entrepreneur is the *persona causa* of economic development (Hébert & Link, 1989). Based on the selected behavioral perspective I narrowed it further down to the definition provided by Wennekers & Thurik (1999) as the preferred definition of entrepreneurship for the remainder of this paper. I also stated that instead of viewing entrepreneurs as synonymous with small firms or the start of a new venture one should view it as a role in the economy carried out by different actors (individuals or firms).

However, even though we know its role, entrepreneurship is still an ill-defined concept. In fact, innovation and entrepreneurship are often interpreted as overlapping concepts, making it difficult for people to distinguish them. This is a notion tracing back to Schumpeter who stated that the entrepreneur is he who carries out *"new combinations we call enterprise; the individuals whose function it is to carry them out we call entrepreneurs"* (1934, p. 74). To clear up this confusion, one first needs to discuss the link with innovation. Only then one can connect the terms further with economic growth.

[9] For instance, Schumpeter's view that entrepreneurs destroy equilibria in markets or Schultz's view on the ability to deal with disequilibria.

3 Innovation

3.1 The notion of "Innovation"

Innovation is a term used frequently nowadays in a wide range of contexts with their own appropriate definition. Innovation, in the field of economics, is closely related with technology on the one hand and knowledge on the other. Technology is defined as "*The goods and services produced and the means by which they are produced in a firm, an industry or an economy.*" (Stoneman, 2002, p. 4). Knowledge is the purest form of technology (Simon, 1973). Knowledge is not the same as information. Information can be easily transferred, stored and codified. Knowledge can be seen as "*consisting of structured information that is difficult to codify and interpret due to its intrinsic indivisibility*" (Braunerhjelm, 2008, p. 466). Knowledge is embodied in organizations or humans.

Innovation is based on knowledge. To innovate is to generate and apply the new technology (knowledge) created in order to solve practical problems. Caution is necessary, new knowledge is not always an innovation[10] and thus a distinction should be made between an *invention* and an *innovation*. "*An invention is the first occurrence of an idea for a new product or process while innovation is the first attempt to carry it out in practice*." according to Fagerberg (2004, p. 4). For an invention to transform into an innovation, adoption and diffusion are necessary which can take up to several decades (Rogers, 2003). Also, this distinction is very important for countries: a country might be good in coming up with the invention but come short on the abilities and resources necessary to commercialize the invention in the form of a product or service. Schumpeter (1934) already made the difference when describing the role of the entrepreneur. He found the creation of a technological opportunity, *i.e.* invention, outside the scope of the entrepreneur's field. Rather, the actual exploitation and identification of the opportunities, *i.e.* innovation, is what a real entrepreneur does.

Further, one can differentiate between product and process innovations. Product innovations concern advancements in the nature or type of product. Process innovations relate to the procedure between input and output. Process innovations are usually associated with lower marginal costs caused for example by new machinery or better raw material. Additionally, one can distinguish between new-to-the-firm and new-to-the-market innovations.

Also, inspired by Schumpeter, one can look at different degrees of innovations, ranging from incremental to radical innovations.[11] The latter is a major innovation, usually a very fundamental step forward while the former is more minor, merely an improvement. Incremental innovations are mostly continuous improvements to a service or product. Schumpeter's interest lies in radical innovations because these have the force to actually shift the market equilibrium (Henderson & Clark, 1990). Radical innovations can also exist in the form of *'technological revolutions'*. These are clusters of innovations which when combined have an enormous effect (Freeman & Soete, 1997).

In this chapter, the term innovation will be further explored by linking it with the concepts of knowledge, entrepreneurship and growth.[12] The relevance of this chapter is obvious: most literature linking entrepreneurship to economic growth proposes that innovation is a crucial intermediate link needed to raise economic prosperity. Also, most literature calls knowledge the basis for innovations. They then see the entrepreneur as the one who transforms knowledge into the different innovations (*e.g.* Block, Thurik & Zhou, 2013).

[10] See also section 3.1.1 "Innovation and knowledge: an introduction"

[11] See section 3.1.5.2 "Degree of innovativeness of entrepreneurship"

[12] Please note that the link between innovation and these three topics have a whole literature per topic. It is not possible nor the goal here to provide a complete overview of this literature. The goal here is to highlight the relevant literature which leads to a coherent framework.

This section is organized as follows. First, an introduction is provided on the main concepts and ideas which I will use in this chapter. Using this chapter as a building block, I first focus on the concept of the knowledge stock, a term which is used in endogenous growth theories and in the theory of the knowledge filter. After laying this foundation, the focus shifts towards the knowledge filter. This part explains the relationship between knowledge and innovation in more detail. I argue that there are differences between the phrases and that newly created knowledge has to go through many phases before becoming an innovation. I argue that one phase should be added to the theory, namely a filter representing access to the knowledge stock. From this point, I also provide a short introduction on the role of intellectual property rights. After this discussion, I focus on knowledge spillovers and their role in standard endogenous growth theories and the Knowledge Spillover Theory of Entrepreneurship (KTSE). The last subsection provides a new synthesis of the spillovers in the classical sense and in the KTSE-sense. I use my new definition of the knowledge filter to bind the two together. Two other subsections provide more details on the role of entrepreneurship, including some empirical evidence. I discuss the innovativeness of entrepreneurs to provide a complete picture. A wrap-up concludes this section.

3.1.1 INNOVATION AND KNOWLEDGE: AN INTRODUCTION

Without knowledge, we would have no innovation; therefore the link between the two is crucial. I assume that a certain knowledge stock is required before one can start to develop innovations. Also, innovations add to the knowledge stock making it a two-way street. The larger the knowledge stock, the more possibilities for innovation will occur. Knowledge is still a very broad concept. In Schumpeter's philosophy knowledge also includes knowledge about markets or about organizations. In order to streamline this concept, one can differentiate between three main types of knowledge (Karlsson & Nystrom, 2006, p. 5-6).

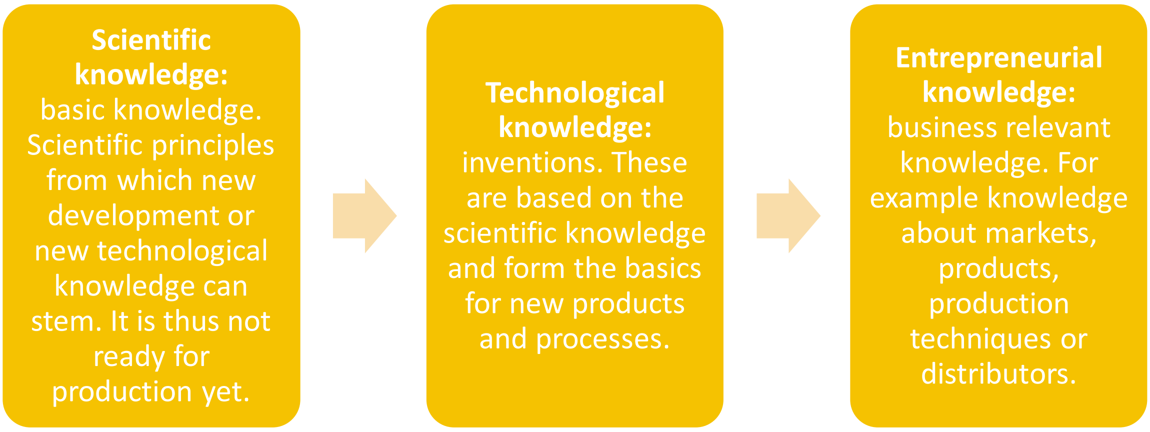

FIGURE 2: ORIGINS OF KNOWLEDGE (SOURCE: KARLSSON & NYSTROM, 2006)

Most scientific knowledge is expected to come from the universities while most technological knowledge is generated by corporate R&D. In this scheme a form of knowledge accumulation is implied, increasing the general knowledge stock. The accumulation also implies that the better one knows the field, the easier it becomes to add additional pieces of knowledge (including entrepreneurial knowledge) within the field. In the literature however this link between knowledge and innovation is often implicitly assumed. Only few articles explicitly model this transformation (*e.g.* Block *et al.* (2013)). Knowledge can thus be viewed as the innovation input while with innovation in the context of this section innovation output is meant.

The OECD characterizes the modern economy as one which is knowledge-based.[13] This is recognition for the fact that knowledge is even more essential for economic development than ever before (OECD, 1996). The knowledge can be embodied in human beings, then referred to as human capital, but can also take the shape of a technology. In such an economy, the innovation (science) system performs key functions. The actors within this system are responsible for knowledge production (development and provision of new knowledge), knowledge transfer (disseminating knowledge and provision of inputs to problem solving) and knowledge transmission (development of human resources, including education). The center of this science system lies with the research laboratories and universities (OECD, 1996). This is due to several developments, one of them being the renewed focus of firms on the link between their research activities and their products. Due to competitive pressure firms want to introduce their products at a fast pace and in return basic scientific research within the firm takes a lower priority (Rosenbloom & Spencer, 1996). Firms do however also use knowledge from the outside world. This is in line with the new 'open innovation' paradigm, made famous by Henry Chesbrough (2003). It assumes that firms need to use internal knowledge but also need to look outside the box of the firm. This paradigm also assumes that during the innovation process knowledge is leaked, for instance in the shape of technology spin-offs or licensing of the research to other firms. The leaked knowledge in turn is then absorbed by other firms. This is one example of knowledge spillovers.

Basic research is nowadays still executed with public support, although the amount of public support is decreasing (Lerner, 2012). Early literature gave theoretical justifications for this support. The essential argument is that the outcome of R&D can always be imitated afterwards. This makes that returns to R&D cannot be appropriated (fully) by the inventor. Given that imitation can be done at a lower cost than the original investment, the incentive of the firm will always be lower than the incentive (or best interest) of society. This is the creation of positive spillovers from the innovation input R&D.[14] In his seminal paper, Richard Nelson (1959) differentiated between basic research, which outcomes could be widely applied, and development expenditures for particular products/processes. The latter can be more easily protected by patents and sorts. He argued that there were external economies involved for the basic research by its numerous potential applications and possible new combinations which would not be used by the firm due to uncertainty. Therefore firms would also try to protect the byproducts of their basic research leading to a suboptimum in research investments. A few years later, Kenneth Arrow (1962a), focused on the non-rival and non-excludable nature of knowledge. Non-excludable means that it is not possible to shield others from the information while non-rival means that when the knowledge is used by one person the amount does not diminish. Others can still use it without subtracting anything from the amount of knowledge. Knowledge is both non-rival and non-excludable, which makes it not attractive to produce for firms. That is why public support is needed: the inventor has little incentive to innovate when he cannot appropriate his returns. Relating this to the concepts of knowledge mentioned above, one could say that technological knowledge is non-rival, but it could be excludable. For instance by using intellectual property regulations as patenting. The non-rival idea comes from the fact that once the scientific knowledge is created the costs have already been incurred. It is costless to use the knowledge again.

As was argued above, not all of this knowledge is created within the organization; indeed the outside world plays a crucial role in the development of knowledge for innovation. When following this assumption, that some of the research is created outside the organization – in line with the open innovation paradigm – it is necessary for the knowledge to flow in order to reach all economic actors (Mueller, 2006). This is the area of *knowledge spillovers*. Spillovers can be defined as knowledge acquired by one actor, without a market transaction (paying) while the creator of the knowledge is not able to obstruct this process of transfer (Grossman & Helpman, 1991). They should not be confused with *knowledge transfers*. These are knowledge flows for which compensation is provided based on the market value (Agarwal, Audretsch & Sarkar, 2010). These spillovers allow more people to

[13] The following definition is proposed by the OECD: "The knowledge-based economy" is an expression coined to describe trends in advanced economies towards greater dependence on knowledge, information and high skill levels, and the increasing need for ready access to all of these by the business and public sectors." (OECD, 2005, paragraph 71)

[14] We will discuss this further below when speaking about the trade-off between protection of intellectual property rights and incentives to innovate. See section 3.1.3 "Knowledge filter".

use the newly created knowledge; it basically means that some agents end up facilitating other agents in their search for innovation. These spillovers might occur intentionally (*e.g.* a scientist disclosing his results) or without intent (*e.g.* a product is imitated). I will come back to the topic of knowledge spillovers in detail in the subsection "3.1.4 knowledge spillovers".

This subsection has provided a short introduction in different topics that are relevant when discussing knowledge and innovation. The next subsections will provide a more in-depth discussion of several topics. I will start with a discussion about the knowledge stock and its components. Then I will look at the concept of the knowledge filter in more detail, followed by additional attention for knowledge spillovers.

3.1.2 Knowledge stock

In the previous section I made a distinction between three types of knowledge. This distinction was made based on the possibilities for application of the knowledge. Now, I can also differentiate based on the 'quality' or 'usefulness' of the knowledge. This is helpful because the concept of innovation also includes the commercialization of the invention or knowledge. The knowledge created, basic or otherwise, is a fundamental ingredient for innovation. Public support can help to create the knowledge, but it is not enough for its commercialization. Private actors are required to convert the knowledge into the innovation (Carlsson, Acs, Audretsch, & Braunerhjelm, 2009). Public support can help to create the knowledge and make the knowledge available but the conversion itself is expected to be done by private actors. Not all knowledge will be commercialized: private actors can or will not commercialize everything. Thus, in line with Arrow (1962a), we should differ between several categories. Arrow (1962b) differentiates between general knowledge and knowledge which is economically useful. In a figure, that looks as follows:

FIGURE 3: COMPONENTS OF KNOWLEDGE

The two types of knowledge combined are the knowledge stock in a country. This knowledge stock is this aggregation of all previously developed knowledge. It contains not only scientific discoveries but also best practices, marketing strategies and new business models (Braunerhjelm, 2010). Linking this dichotomy to the distinction made in the previous subsection has the following implication: the total knowledge stock forms the aggregation of scientific, technological and entrepreneurial knowledge. These types of knowledge can also be divided into general and economically valuable knowledge. For example, not all scientific knowledge will be the basis for (new or improved) production, so not all will be denoted as economically valuable, although both are part of the knowledge stock.

The distinction between the two forms of knowledge is related to questions around the gap between knowledge creation in a region and the actual amount used in commercialization there. At the optimum all created knowledge should be valuable however this is not the reality. An example is Europe, where the gap plays a role in the discussion around the European paradox.[15] This is the gap between all knowledge created and the part which actually leads to results. Thus, as shown in figure 3 part of the created knowledge will be economically valuable while the other part will remain in the general knowledge category. As stated before, ultimately the goal is to have as much economically valuable knowledge as possible. The paradox is between high levels of investments by both private and public parties (including universities & research institutes) which do not result

[15] Also see chapter 1 "Introduction" for a brief discussion on the concept.

in high levels of growth and commercialization (Audretsch, 2009). The paradox also sees on the quality of research, not (only) on the quantity. It entails that Europe is excellent in research compared to its major competitors while having trouble to transform the knowledge in competitive advantages (European Commission, 1995). The point made is interesting; Europe has a problem to create economically valuable knowledge or to transform knowledge into innovation.

3.1.3 Knowledge filter

Putting the discussion if Europe's research is as excellent as proclaimed aside, I will analyze the process between knowledge and innovation in more detail. I have made some introductions on where knowledge originates. Also the idea has been presented that knowledge is not a homogeneous term but that differences in type and usefulness of knowledge exist. That is why the focus now shifts to the process which transforms knowledge into innovation. One set-up of this process is visualized in figure 4 below:

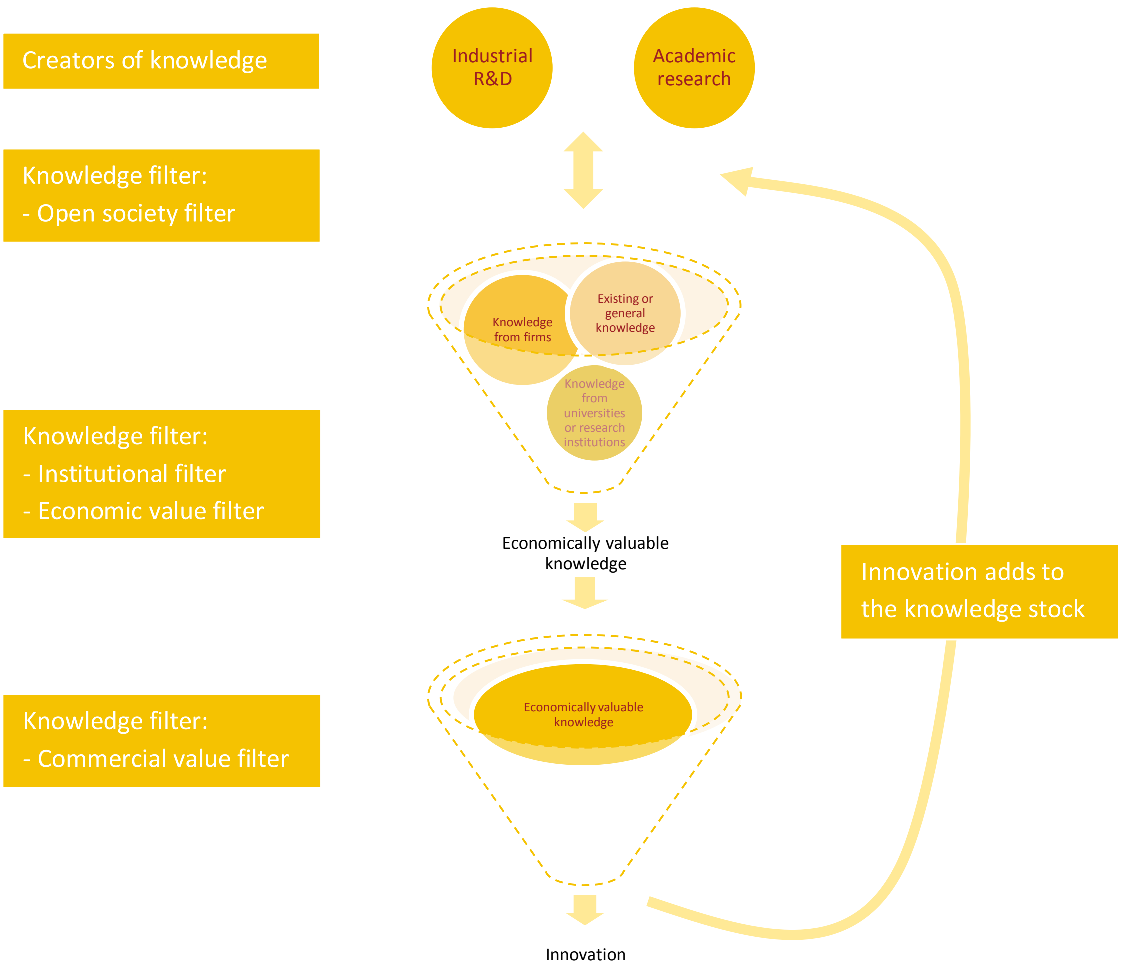

FIGURE 4: FROM KNOWLEDGE TO INNOVATION

Figure 4 gives a schematic overview of this process. First, academic and industrial research are represented as the two prime suppliers of knowledge (Carlsson *et al.*, 2009). They are thus the two providers of new inputs in the innovation process. These inputs might be R&D investments but also personal skills or knowledge. This is in line with the knowledge production function approach which suggests both industry and university research to be the sources of innovation (Jaffe, 1986; 1989; Griliches, 1979). The existing knowledge (knowledge stock) is represented by the content of the upper and lower funnel. The two funnels symbolize a two-step selection mechanism from knowledge towards innovation. The funnels represent that not all input will come out on the other side: the amount of input exceeds the output. In the picture, the process is symbolized in two steps: the two funnels together represent the *knowledge filter*. This filter can be attributed to many factors but is in essence a mediating feature between knowledge and economic activity. Acs *et al*. (2004) see the filter as a *'semi-permeable barrier'* which limits transformation of all knowledge into new economic activity. It represents a broad range of institutions, culture, regulations and rules. In my view, the knowledge filter can then also be interpreted as a mediating factor between Arrow's (1962a) general knowledge and economically beneficial knowledge. In the sense that knowledge which does not lead to economic growth is left behind in the filter. The left behind knowledge is what I have denoted above as general knowledge. Only the economically valuable knowledge passes the first step of the knowledge filter. Only a part of the economically valuable knowledge passes stage two of the knowledge filter. This part of the filter focuses on possibilities for commercial applications, which in turn represents that commercialization is necessary before one can speak of true innovation. Thus, for knowledge to turn into innovation and ultimately economic growth, the knowledge filter should first be penetrated. As a final remark, please note that general knowledge can be used as an innovation input in the system multiple times because the knowledge which is useful for one innovation does not have to be useful for the other innovation. The character of the knowledge as economically valuable or general is thus temporary. All knowledge which is an input in the funnel can then be recycled in new innovation attempts. It remains in the upper or lower funnel. Both funnels have dashed outlines, indicating that the knowledge can be recycled. How thick the walls are of the funnel represents if the other members of society can benefit from the already existing knowledge. This is the open society filter.[16]

Acs *et al.* (2004; 2009) identify two vehicles, incumbents and start-ups (entrepreneurs), who can break through the filter. This is what they call the Knowledge Spillover Theory of Entrepreneurship.[17] These organizations allocate significant amounts of effort and funds to select valuable information for their innovations and leave the other knowledge behind. The filter is then a summation of all factors which prohibit free flow of knowledge (spillovers). Mueller (2006) argues that this view, of only focusing on new firms and incumbents, is too short-sighted: she argues that university-industry relations should be reviewed as well, namely as a mechanism to lead the valuable knowledge spillovers through the filter towards innovations. The universities can produce the knowledge which will be commercialized through connections with the outside world. The university will have contact with the industry. For instance, they can work together with SMEs in order to commercialize their knowledge in the Research for the Benefits of SMEs Program[18] in the Seventh European Framework Program. In these projects the European Union subsidizes SMEs who want to make use of the research capabilities of research institutions (CORDIS, 2007). In short, the university-industry relations and entrepreneurship can be an additional force for breaking the knowledge filter and stimulating innovations, according to Mueller (2006).

This knowledge filter can be further described as the summation of four separate filters, as shown in the following figure 5:

FIGURE 5: KNOWLEDGE FILTER

This is another representation of the parts of the knowledge filter which were also visualized in figure 4. The first filter I discuss is the institutional filter. This filter is only applicable for the research provided by academics and

[16] See figure 5 for another representation.

[17] For the complete model and underlying assumptions, please see Acs *et al*. (2009). Also, for the empirical connection with economic growth see Braunerhjelm *et al*. (2010). Lastly, for a discussion of this model within this paper, see chapter 4.

[18] Small- and Medium-sized Enterprises

research institutes according to Carlsson *et al.* (2009). This filter consists of barriers as organizational barriers, politics in the universities and the lack of incentives for researchers to work towards commercialization. When all these hurdles are overcome, the invention becomes disclosed. This is the phase were the economic value filter comes into play, which exists for both industrial and academic research. Here, the invention has to prove to be of such nature that it increases the welfare within the economy. Carlsson *et al*. (2009) state that after the invention has broken the economic value filter for academic research, it first lands in the intermediate stage. In this stage, it has to be determined if the economically valuable invention can actually be sold; the commercial value test. It basically revolves around the question if money can be made of the invention. If the answer is yes, the commercial value filter is taken down. Commercialization can then occur in the form of licensing of the property or by new start-ups in the case the origin lies in academic research. For industrial research, options are also to create a spin-off (corporate entrepreneurship) or to expand the current business of the firm.

Open society filter

In my view there exists an additional filter; the one which revolves around how open society is and how accessible the knowledge stock is. In figure 5, this one is represented on the left, making it the first step. In figure 4 it is represented by the dashed lines of the funnels. Connecting the idea of an open innovation society and knowledge as the seed for innovation makes it also important to think about how firms can get access to knowledge. They need access to the knowledge stock to have the fuel for their inventions. This can also be linked to figure 2 where an accumulation of knowledge was visible. The accumulation stems from the idea that you need scientific knowledge in order to create technological knowledge etc. To make this process possible means that the creator of technological knowledge should have access to the knowledge stock, because he needs the basic scientific knowledge to progress. Without the access, and thus with a very thick open society filter, innovation inputs are largely hindered. The knowledge to which the firm or creator needs access can be from all of the categories of knowledge from figure 2, depending on the stage of the innovation process. Entrepreneurial knowledge for example is very important in the last stage. It is closely connected to what is necessary to actually introduce the innovation. The innovation output can be of all five types of newness that Schumpeter (1934) distinguishes: new product, new process, new market, new source of supply or a new organization. The innovation can also be a combination of different types of knowledge. For example when the entrepreneurial knowledge is applied on technological knowledge and both thus serve as innovation inputs for the final innovation.

The open society filter is also connected with the idea of appropriation of returns to R&D as touched upon in the subsection on ‘Innovation and knowledge: an introduction’. I showed that public support was needed in order to create knowledge. The public support helps to offset the negative effects that the lack of innovation (invention or R&D) protection can have on the incentive to innovate. This means that a trade-off is taking shape: stronger intellectual protection versus the access to the knowledge stock. The trade-off is between advantages and disadvantages for economic growth of the strictness of Intellectual Property Rights (IPR). It is the trade-off between a stronger incentive to innovate (because of higher appropriability options for newly created knowledge) versus access to the knowledge stock. If a society has a strong system which protects intellectual property, it is likely that the basic knowledge needed to create the innovation will be more difficult to access. Thus, intellectual property rights mitigate in the relation between private gain and public welfare.

Intellectual property rights reduce the uncertainty around R&D activities. It gives the inventor more security around the possibility to appropriate returns on his investment. They are created to protect inventors against the possibility of imitation by either foreign or domestic competitors. When the competitor does have access, he is able to offer the product or production process, and usually at lower prices (Ginarte & Park, 1997). In economic terms, this does hinder the inventor in getting his monopoly rents from the R&D activity. This explains the reason why countries have invested time and money in creating patent and intellectual property laws. The government creates a safe environment in order to help its domestic companies. This is another mechanism next to the monetary support as discussed above. The relationship may also be related to trade: some empirical evidence suggests that if a country is not open, higher intellectual property rights may not be the stimulus which increases innovation (Braga & Willmore, 1991). They do have less incentive to innovate anyway, because the incentive coming from the fear of foreign competitors is lacking. In contrast, open regimes may have a more direct link between intellectual property protection and incentives to innovate because they are stimulated to innovate anyway to protect themselves from foreigners. And, on the other hand, if a domestic company wants to buy intellectual property from another foreign firm, they need to be able to guarantee the protection to them; otherwise the foreign company might be very hesitant to share his knowledge (Sherwood, 1990; Mansfield, 1994).

A case can also be made for weak(-er) intellectual property protection. Key here is the cheap and free access to the knowledge stock: a thinner knowledge filter. If the protection of knowledge is weaker, this access is more secured. Knowledge spillovers are thus easier to occur in a country with a weak protecting structure. Also, if the degree of protection is very high, incumbents might use the patents to deter entry. They might keep *'sleeping patents'*. These are patents which are not utilized at the moment but make it very hard for newcomers (*e.g.* entrepreneurs) to enter the market (Gilbert & Newbery, 1982).

Empirically, the idea of stronger IPR stimulating innovation is confirmed by Varsakelis (2001) who finds that in countries with a strong degree of patent protection the R&D intensity is also higher. Gould & Gruben (1996) find that stronger intellectual property rights relate to higher economic growth levels. Both studies find that trade openness does have a positive effect on the dependent variable as well. Park & Ginarte (1997) find a similar result when studying economic growth and intellectual property rights. They use a Cobb-Douglas production function with an additional variable that captures institutions. Their conclusion is that stronger intellectual property rights have the potential to boost economic growth, because of their stimulating effect on innovation. Their results differ for developed and developing countries: IPR has a positive effect on developed countries while this effect is lacking for the developing countries.[19] Falvey, Foster & Greenaway (2006) focus on the same research question using threshold regression analysis for 79 countries. They find that IPR protection is positively related to growth for both high and low income countries, but not for the middleclass. Their explanation is that IPR in middle-income countries generates losses because it reduces possibilities for imitation while in high-income countries innovation is encouraged and in low-income countries technology flows are now possible.

A possible explanation for this effect on less developed countries, keeping in mind the framework presented in this paper, might be that in developing countries another factor plays a role: the possibility for the entrepreneur to perceive the opportunity. With this I propose that in developing countries, even though the protection of property rights may be weak or strong, this is less relevant because the ability to work with the knowledge is lacking. Thus, there is no vehicle strong enough to break through the knowledge filter. The actors (entrepreneurs, incumbents) are not equipped to work with the provided knowledge. Qian's (2007) findings endorse this proposition. She finds in a sample of pharmaceutical firms in 26 countries between 1978 and 2002 that stronger IPR has an accelerating effect on innovation when a country has high educational attainment, a high level of economic development and higher levels of economic freedom. Thus, she finds the positive effect when the country is developed. The educational attainment for example is something that the entrepreneur will need in order to break for the knowledge filter. If this is not available, the access to the knowledge stock filter is less important because it is not possible to work with the knowledge even if access is there.

Other literature has focused specifically on the trade-off. Acs & Sanders (2012) model this trade-off in an endogenous growth model with explicit attention for the entrepreneur. Their model distinguishes between innovators and inventors. From this distinction, they gather that the stronger protection of intellectual property rights has an effect on economic growth in the form of an inverted U-shape. The inverted U-shape resembles the two points I discussed before: strengthening patent protection increases the incentive to innovate because the inventor can get rents for the commercial exploitation of their product. This has a positive influence in the first place because the new innovation has a positive effect on the economic growth rate. The rents which the

[19] Falvey, Foster & Memevoci (2006) and Qian (2007) find a similar result.

inventor can now receive would otherwise been appropriated by the entrepreneur. This is the reward for the entrepreneur to take the risk, invest his time and provide the organization. After some point however, the positive effect is off-set by the negative effect because entrepreneurs face such a low return that they will not act anymore. Empirically, Vichyanond (2009) found a similar result working with an industry level dataset for the US. He researched the connection between exports in the industry and the level of patent protection. He found that below a certain threshold stronger patent laws had a positive effect on exports, while after the thresholds this effect was reversed. He thus found an inverse U-shape.

Other empirical evidence has picked-up on the above suggested trade-off as well. Jaffe & Lerner (2004) argue in their book about the US patent system that the system has become too strong. They illustrate this with the example of Texas Instruments. In this company, specialized in designing and manufacturing semiconductors, the patent enforcement center forms the second largest profit center. Along with other examples, they argue that the protection in the US is now beyond the optimum which leads to hurting the innovation process. They argue that the incentives for commercialization are taken away leading to economic losses. Applying this to the discussion of the knowledge filter means that I can relate that they think that the access to the knowledge stock is now so expensive that other companies will not use the available knowledge. The open society filter has become too strong, making it very hard to breach. This makes it difficult for others to get the knowledge required to develop further innovations. Qian (2007) actually finds this optimum in her paper on the pharmaceutical industry. She includes a quadratic term in the regression in order to find the optimum. She states that there seems to be a level above which the further enhancement of the IPR-regime has a negative effect on innovative activities.

In summary, this subsection established the relationship between knowledge and innovation. It was explained that knowledge is the soil from which innovation grows. I also showed that the relation is not as straightforward: spillovers help to make knowledge accessible for all but diminish the returns to R&D for inventors possibly lowering the knowledge creation. Also knowledge should first survive the knowledge filter before it can be used in products. We saw that the knowledge filter consists of several hurdles which have to be taken before the commercialization of the knowledge, the innovation, is completed. I have proposed an additional hurdle: a filter which is the first step, named 'open society'. This is the filter through which the initial seeds for the research have to pass before they go to the institutional filter or economic value stage. This filter is also consistent with the idea of knowledge spillovers in the sense of the Grossman & Helpman (1991).[20] It reflects how difficult it is for companies to get access to these spillovers and use them in their products. The easier it is to get access, the thinner the filter will be.

3.1.4 Knowledge spillovers

In the previous subsection the focus was on the knowledge filter. I described a trade-off between incentives to innovate on the one hand and the open society filter on the other hand. Closely related to this discussion is the idea of knowledge spillovers. When spillovers occur, someone else can benefit freely from another's R&D efforts. This lowers the incentive to produce R&D, but provides on the other hand also opportunities for others. These opportunities can be commercialized leading to economic growth. This is a central thesis in modern economic growth models. In this subsection, I will discuss some models in more detail. Further, I distinguish between the definition and idea of knowledge spillovers used in the Knowledge Spillover Theory of Entrepreneurship and knowledge spillovers in the classical sense.

[20] I will discuss knowledge spillovers in a different sense below in subsection 3.1.4.1 "Knowledge spillovers in the Knowledge Spillover Theory of Entrepreneurship".

3.1.4.1 Knowledge spillovers in growth models

Innovation – especially in the sense of knowledge spillovers – is crucial in models of economic growth. Most models assume that after correcting for labor and capital, the real economic growth should come from innovation. I will now discuss several of these growth models and discuss explicitly the role that innovation plays in these models.[21] First traditional growth models will be discussed, second the Knowledge Spillover Theory of Entrepreneurship.

Knowledge spillovers in traditional growth models

Solow's (1956) neoclassical models focused on two factors of input: capital and labor. The model gave us the insight that when a '*steady state'* was reached, technological progress was a necessary factor to improve economic prosperity. Labor and capital were then at a point that they remained constant. Based on these factors, and an assumed, mathematical constant rate of technological change (innovation), the model made predictions on how economic growth would prosper. Soon, the realization came that the predicted levels of growth and the actual growth started to drift apart. These differences are known as the *'Solow residual'* or *'technological residual'*. This residual was often contributed to new technology and knowledge which was used in the production. However, variables explaining this residual were not captured in the original Solow model; technological growth remained exogenous. Innovation thus played a role but the model did not provide an explanation for its source and magnitude.

The next generation of models did internalize technology; hence the name endogenous growth models (Romer, 1986; 1990). These models chose to incorporate knowledge as a variable and were able to explain more of the growth residual compared with the neoclassical models. The model combined human capital with creation of new technologies by introducing a sector where people created innovations. In this R&D sector, human capital combined with the existing technologies (knowledge stock) created new designs. The labor (human capital) necessary was provided by the household sector of the economy. Thus it is R&D expenditures in the model which leads to innovation and growth. The interesting feature of the model is that it accounts for two effects of knowledge: profit-maximizing firms become more productive on the one hand and on the other it allows for the possibility of knowledge spillovers.[22] It allows these spillovers to shift the production functions due to these technological improvements. The spillovers allow other firms to increase their ability to make new products, improvements or enhance process efficiency, thus providing key opportunities for these firms and industries (Romer, 1986). They thereby develop other inventions and progress. These two effects make knowledge stronger than the single effects that the other factors, labor and capital can reach (Acs *et al.*, 2004). Because knowledge was treated as a separate factor, even if capital and labor remained constant an increase in growth could still occur via a knowledge increase. Now that the creation of new technologies is explained fully by the economic characteristics inside the model, we referred to the model as the endogenous growth models. Policy implications from this model are for instance that we should improve human capital further, by for example education, or investments in R&D help to bring the economy to a higher level (Romer, 1994). The endogenous growth model has allowed us a large leap in understanding the drivers of growth compared to the Solow model, using knowledge spillovers as a key element.

A downside of these models – as mentioned above – is the assumption that the knowledge spillovers are automatic, without any restraints. It assumes that knowledge spillovers are exogenous. The model thus only explains knowledge creation but ignores the issue of knowledge diffusion. However, we know from empirical evidence that this not the correct. Spillovers are restricted by cost constrains, absorptive capacity constraints and legal and geographic constraints (Cohen & Levinthal, 1990; Jaffe, 1989; Jaffe, Tratjenberg & Henderson, 1993). These limitations were partly solved in the second generation of endogenous growth models: the neo-

[21] Full explanation of the macro-economic growth models are beyond the scope of this section. The goal of this section is to provide the introduction on how innovation and growth are related and present different points of view. This section draws, upon others, for background information on the book Advanced Macroeconomics by David Romer (2012).

[22] Defined as the transfer of knowledge from industry or firm *i* to industry or firm *j* (Acs & Plummer, 2005).

Schumpeterian models (*e.g.* Aghion & Howitt, 1992; Segerstrom, 1991; Cheng & Dinopoulos, 1992). These models introduced the concept of a R&D race. Basing their concepts on Schumpeter, they now modeled that only a few innovations came from the R&D races. In current years, the focus of these models has become even more refined. Entry and firm heterogeneity received a more prominent spot, for instance in the model of Aghion *et al.* (2009). This model differentiates between firms which were on the frontlines of technological progress and the laggards. It showed that entrance positively affected the leading firms while no effects were found on the laggards. The neo-Schumpeterian models still focused more on the incumbents which were involved in these races than the 'real' entrepreneur (Braunerhjelm, 2008). Another comment is that the neo-Schumpeterian models combine the inventive and innovative stages into one. This is not in line with Schumpeter who advocated a clear distinction, with the concurrence as an exception to the rule (Schumpeter, 1934).

Back then (especially in the eighties and early nineties), almost no scholars involved with these models had any attention for entrepreneurship. This although Schumpeter already placed attention on the role of the entrepreneur back in 1911 and empirical evidence suggested that higher levels of entrepreneurship were highly correlated with higher levels of growth (Van Praag & Versloot, 2007). Entrepreneurs were just treated as part of the residual which remained unexplained (Baumol, 1993). Although attention towards entrepreneurship started to build during the course of the nineties, it still took a long time before the first models came.[23] Only recently formal theories started to appear that paid attention to the role that entrepreneurship plays in order to create economic growth (Acs *et al*., 2004; 2009). It is only now that the Schumpeterian entrepreneur is starting to get incorporated in order to bridge the gap between entrepreneurial opportunities on the one hand and economic output on the other. In the next subsection, I will elaborate on these new growth models by introducing the entrepreneur.

Knowledge spillovers in the Knowledge Spillover Theory of Entrepreneurship[24]

The new growth theory, where knowledge is the key vehicle in enhancing productivity, assumes that knowledge spillovers occur automatically (*e.g.* Romer, 1986; Lucas, 1988).[25] These theories assume that knowledge is a public good (non-rival, non-excludable) which everyone can use (Cantner, Gaffard, & Nesta, 2008). Empirically, conversely, multiple articles have found that restrictions exist. For example, due to intellectual property rights (Cohen, Nelson, & Walsh, 2000), the absorption capacity[26] or due to the relationship between the creator of the spillover and the receiver (Jaffe, 1989). In response to this oversight in the earlier models, Acs *et al.* (2009) propose a new theory in which there are two vehicles which can absorb these spillovers: the incorporation of new knowledge into the business routines of existing firms or the start of new ventures to exploit the knowledge. Universities (and other research institutes) can be the source of the knowledge causing spillovers to occur. Entrepreneurs are also supposed to be creators of knowledge and can thus be the source of spillovers.

The theory referred to is known by the name of the Knowledge Spillover Theory of Entrepreneurship (KTSE). This theory, made famous by Acs, Audretsch and their partners, introduces both entrepreneurship as well as endogenous spillovers in a model (*e.g.* Acs *et al.,* 2009; Audretsch *et al.*, 2006; Audretsch & Lehmann, 2005). The spillovers are endogenous because the knowledge spillovers are determined within the model by new firm start-ups which are in turn created by entrepreneurs. Braunerhjelm, Acs, Audretsch & Carlsson (2010) created the extension for the endogenous growth models (*i.e.* Romer's 1990 model) and combined it with the knowledge spillover theory of entrepreneurship. Thus connecting it with endogenous growth. Empirically, Braunerhjelm *et al.* (2010) found that spillover entrepreneurship has a positive effect on economic growth, after controlling for R&D activity. The key of the theory is that entrepreneurs create new firms because they see entrepreneurial opportunities based on knowledge spillovers. This is one example of a difference between knowledge spillovers in the classical sense and how the term is used in the KTSE-theory. Here spillovers are limited to the start of new

[23] See also chapter 1 "Introduction".
[24] This model forms the basis for the empirical exercise of this paper. I will discuss the technicalities in-depth in chapter 4.
[25] See also subsection above under "Knowledge spillovers in traditional growth models".
[26] See also subsection 3.1.5 "Innovation, knowledge and entrepreneurship".

firms while such a restriction does not apply in the classical sense. These new firms use the knowledge created by others (incumbents, research firms) and commercialize them. It is thus crucial in the theory that incumbents and others create the knowledge, not the entrepreneur himself. These creators have a different opinion on the value of the knowledge and hence do not commercialize it themselves. This could be a researcher who really believes in his product but is not allowed to follow-up on it within the boundaries of his firm. This researcher might take his knowledge with him to start a firm of his own. An example is Intel which was created by former employees of Fairchild. Two of the founders of Intel were researchers at Fairchild, Gordon Moore (physicist and chemist) and Robert Noyce (physicist, inventor of the integrated circuit). Another option might be universities which are non-profit organizations and are not commercially oriented. A researcher might then be forced to take his invention outside and start a new business. A note applies here: in the final model of this theory, entrepreneurs are considered as creators of technological change or innovations. Again it is crucial to discriminate between technological progress (innovation), the innovation output and knowledge as an innovation input. The entrepreneur is involved in the creation of the former but not in the latter.

The model as presented by Braunerhjelm *et al*. (2010) can be described in short as follows:

- There are two methods to develop new products: entrepreneurs and incumbents. The new products are thus the innovation outputs.
- The model has three different factors of production: labor, capital and entrepreneurship.
- The differentiated products are open to economies of scale.
- Not all people are good at being entrepreneurs; there are differences in entrepreneurial abilities.
- Increasing R&D results in an increasing the number of new products (processes, combinations, varieties etc.).
- The economy consists of three sectors: R&D, final goods and entrepreneurship. The labor force will be divided over these sectors.

One novelty in the model is how entrepreneurship is specified: it is the summation of the entrepreneurial ability of each person, the total knowledge stock and how susceptible the economy is for entrepreneurial activities. When solving the model, the outcome is that the rate of technological progress depends on the rate of entrepreneurial activity, R&D expenditures and how efficient these are. Thus, by making entrepreneurship endogenous, the theory combines the idea of entrepreneurial opportunities and spillovers into one model. It provides an explanation of these spillovers which was lacking in the new growth and knowledge production function models. It helps us thereby to understand how knowledge, innovation and entrepreneurship are intertwined. Another novelty in the model is that it does not assume that all knowledge is economically valuable. It does this by assuming that entrepreneurs only use that subset of the knowledge stock that is useful for them and can result in opportunities and consequentially growth. This is how entrepreneurs are responsible for innovation, but they are not (automatically) involved in R&D activities. They introduce new products based on the current knowledge stock. In other words, knowledge spillovers to the economy are at large the result of commercialization and the activity of entrepreneurs. The knowledge created by inventors helps future inventions once it is actually commercialized. This resulted in making knowledge creation on the one hand and commercialization on the other dynamic complements which together result in economic growth. Here the knowledge filter is visible: knowledge is the innovation input which needs to be commercialized (innovation output). This process and choice in the theory thus resembles the knowledge filter.

Empirical evidence has been provided on the relationship between entrepreneurship and growth. For example, Carree & Thurik (1999) find that countries with high increases in entrepreneurship simultaneously experience higher levels of growth. Audretsch & Thurik (2002) provided one experiment with the relative share of small firms in economic activity as measure of entrepreneurship. They also provided an analysis using self-employment as the variable reflecting entrepreneurship. For both analyses, which use different time periods, their conclusion is the same: higher entrepreneurial activity seems to result in higher growth rates. Van Stel, Carree & Thurik (2005) find that total entrepreneurial activity is also related with economic growth. However, they find that this effect depends on the level of per capita income in the country.

Still, even though the KTSE-theory has resulted in a large step forward, fits our current mindset and introduces a mechanism to deal with the knowledge filter (entrepreneur), the model has not been without criticism. Two stories can be told using the theory: opportunities exist because others (universities, incumbents) have not utilized them and secondly, these opportunities are seized by creating new firms. The ones creating these new firms are the entrepreneurs. It seems obvious that the entrepreneurs who are the ones exploring these opportunities are usually the ones who are unhappy with the way their research is handled in the incumbent or research institution. Thus, one could say that the theory mostly explains the entrepreneurial choice of a researcher. This view seems limited for the pluralism entrepreneurship embodies.

Comparison of the definitions of knowledge spillovers

Knowledge spillovers thus play an important role in models for economic growth. They do not however have the same implications and meaning in the different models. Knowledge spillovers in the classical sense are defined very broad. As we saw before they can be defined *"as knowledge acquired by one actor, without a market transaction (paying) while the creator of the knowledge is not able to obstruct this process of transfer"* (Grossman & Helpman, 1991). In the knowledge spillover theory of entrepreneurship, spillovers are defined less broad. In this paragraph I will discuss some of these differences and try to explain the connection between them.

Knowledge spillovers in the classical sense are the reason for economic growth. As we saw before, these spillovers are the key element for the endogenous growth. In the Solow model, knowledge creation was still exogenous but the progress in the endogenous growth models was internalizing the knowledge creation. As explained this was done by adding another business sector where knowledge was being created. However, knowledge spillovers did occur automatically and the mechanism supporting it was not internalized. Thus, even though knowledge creation was endogenous, knowledge spillovers were still exogenous. In theory, this has the implication that firms can enhance their own knowledge stock for free. They can use the knowledge of others. This makes the connection with economic growth very direct. In the classical models, two characteristics of knowledge are very important: it is non-rival and non-excludable.[27] These characteristics allow knowledge spillovers to exist. In other terms, these characteristics make that knowledge spillovers are not possible to prevent.

In the knowledge spillover theory of entrepreneurship, knowledge spillovers are more used as a mechanism for providing entrepreneurs with opportunities. One could almost argue that the knowledge spillovers are synonyms for economic opportunities in that theory. The theory argues that in a context where knowledge is highly available, more economic entrepreneurial opportunities arise. Thus, the connection is very strong.

Another difference between classical spillovers and KTSE-spillovers is the requirement of the new firm. The KTSE-theory assumes that a knowledge incubator exists (Acs, Audretsch, & Lehmann, 2013). This can be a private firm, government, university, research institution or NGO, but key is that it already exists. This knowledge incubator has created knowledge which has the potential to be commercialized. However, the incubator does not choose to do so. This means that a new firm – or entrepreneur – is a requirement for the knowledge spillover. Classical sense knowledge spillovers do not impose this restriction. It just assumes that there is another third party which assesses the knowledge with fewer costs. The result is that the link with economic growth in KTSE is more indirect because of the added requirement of the new firm.

The third difference has also to do with the concept of the knowledge incubator. It is very clear from the theory that the knowledge incubator makes a clear choice not to use its knowledge. This might have to do with uncertainty or the will to focus on other priorities for the time being. This clear choice leads to possibilities for a

[27] See also section 3.1 "Innovation and knowledge: an introduction".

knowledge spillover. Relating this to the concept of the knowledge filter: the choice not to innovate results in the knowledge filter becoming much thinner. Thus, making it possible for the entrepreneur to access the knowledge and use it to his advantage. This 'choice moment' does not exist for classical knowledge spillovers. They just exist. This is because the inventor of the knowledge is not able to protect it. The knowledge is non-excludable, which means that others cannot be excluded from using it to their advantage.

Related to this fourth difference is the idea that knowledge spillovers result from different values. For the third difference I focused on the choice, this difference focuses on how this choice is made. The KTSE-theory believes that the choice is made because entrepreneurs and incubators have different opinions on the economic value of the knowledge. The main idea is that the creator of the knowledge feels that it is not useful for him or cannot give him the monetary reward which he anticipates. The incubator believes that the knowledge is not suitable for them while the entrepreneur believes in the economic potential. This might be related to the fact that the entrepreneur only has to bear part of the costs of the innovation. He does not bear the full-costs of developing the innovation. This advantage might explain the difference in judgment. In the classical sense, knowledge spillovers are not the result of different opinions on the knowledge but on the fact that you cannot protect your knowledge. The knowledge spillovers in the classical sense are more based on the idea that you cannot screen the knowledge of from potential users. The decision element is thus not available there.

Fifth, the KTSE-spillover theory states that entrepreneurs should be *able* to absorb the knowledge and convert it to economic knowledge. This means that the entrepreneur needs to have some skills and knowledge himself in order to be able to use the selected spillovers. The entrepreneur does turn the knowledge into economic knowledge by going through the knowledge filter. This requirement on the breach of the knowledge filter is not mentioned so explicitly in the classical growth models.

Furthermore, the idea in the KTSE-theory of spillovers is very limited. They assume that the rejected knowledge of the incumbent lands with only *one* other firm, as a result of the idea that the knowledge is internalized by the inventor. The inventor then starts the new firm. Knowledge spillovers in the classical sense are not limited to a number of people. This belief is related to the non-excludable nature of knowledge. This has as a consequence that many people can use the knowledge and that the new knowledge is not limited to one user. It can be used by many people who do not limit others from using it. The KTSE-theory assumes that only one entrepreneur receives the benefits of the knowledge. He is the one who fulfills the entrepreneurial opportunity after which the option is exhausted. Thus, classical spillovers have more beneficiaries.

Another point is the limited version in how spillovers can occur. I focus on the explained connection between the new firm and the knowledge incubator. In this paper the wider view of Schumpeterian entrepreneurship was already chosen. It has been argued in the second chapter that most entrepreneurs will not be scientists or researchers. They may be students or (former) managers without a background in R&D. Also, one could argue that it would be a difficult decision for the scientist to leave his – generally – good current job behind to dive into the usually more risky world of entrepreneurship. In my view, the limitation of the KTSE-model also touches upon the difference between invention and innovation. With the narrow focus on a researcher with an idea, one focuses mostly on the inventor. If he then takes the leap, he will be an innovator as well. The model thus always assumes that the inventor and innovator is the same person. The model does consequently ignore the idea of an entrepreneur, the innovator who is not also the inventor. This second person then uses knowledge of others to start their firm. These are also knowledge spillovers, namely personal spillovers. The theory limits itself to the organizational level (research firms, incumbents) but does not discuss interpersonal spillovers. For instance, inventors who talk to another person who provides the business side information and management of the new firm. These are covered by the definition of classical knowledge spillovers I provided above but not by the idea of the KTSE-model. Thus, these interpersonal spillovers should be considered in an extension of the model.

Besides, the definitions of knowledge are different within KTSE and in endogenous growth models. The classical sense does not provide a clear description of the type of knowledge, but I can deduct from the models that they count all knowledge as economic knowledge. The KTSE-theory does not do this but explicitly assumes that there is a step (*i.e.* the knowledge filter) which has to be taken. In the KTSE-theory commercialization is a necessary hurdle in order to speak of knowledge. Thus again a more strict definition is used. This point needs a critical note. In the different papers on the KTSE-theory, different definitions of the term knowledge have been used. I have adapted a definition above, mentioning a difference between knowledge on the one hand and knowledge stock on the other. Knowledge is one bit, while all knowledge together constitutes the knowledge stock. I also made a difference between technology, innovation and knowledge. The authors of this theory have been ambiguous in their definitions. For instance, Audretsch & Lehmann (2005) focus on "new knowledge and ideas" as basis for the entrepreneurial opportunities while a few years later Acs *et al*. (2009) refer to an increase in the knowledge stock. I deduct that the knowledge stock referred to by the authors is the same as I use in this paper. Separate from the definition of knowledge, the theory also does not internalize the creation of knowledge. It only provides a source for the knowledge, not how this source works. It focuses on the knowledge which is embedded in the worker. This worker then leaves to start the new firm (Audretsch & Lehmann, 2005). This is a clear limitation, especially because the theory puts such emphasis on these entrepreneurial opportunities. It is only the firm creation which is endogenous. This process is explicitly modeled in the endogenous growth models of for example Romer (1990). Here knowledge is a function of the knowledge stock and human capital available.

There is also a question related to the type of knowledge I can talk about. I could view knowledge as an innovation input but one could also look at in as only knowledge about the final product. The latter is in the sense of imitation; the knowledge about the final product helps other firms to copy this. This can then be considered as *new-to-the-firm* innovation. This helps one firm to be more productive with the free required knowledge, directly influencing economic growth. The knowledge as an input for innovation is the other type. This is more the *new-to-the-market* type of innovation. Question is what type of knowledge spills over easier. One could argue that this all depends on how well the knowledge is accessible. For instance, new production processes are more easily protected because they are within the firm: they can be less visible. Final products can be in the hands of others which can use reverse engineering. However, this latter effect might be mitigated by proper intellectual property rights protection.

In summary, I can state that the view of the classical spillovers is broader. It has fewer limitations and is based on the two characteristics of knowledge: non-excludable and non-rival. The KTSE-theory has many limitations resulting in the differences between both theories. Many of these differences can be explained by using the earlier introduced concept of the knowledge filter, with special attention to the open society filter. In the classical sense is the open society filter much thinner: the knowledge is widely available and accessible. In extreme terms: everybody can use it to his or her advantage. The spillovers are widely present. The KTSE-theory's limitations make that the open society or easy access to the knowledge stock difficult to achieve. One illustration is that the incumbent first has to make a decision about not using the knowledge while this threshold is not present in the endogenous growth models. The theory assumes that entrepreneurs will only start new firms based on the access to the knowledge spillovers. In the classical sense knowledge spillovers increase the knowledge stock for free, which allows other firms to increase their productivity for free. In the end, this leads to a direct effect on economic growth.

Classical sense knowledge spillovers are free of charge. This is not a realistic assumption. In KTSE-theory, knowledge spillovers are too narrowly defined which is also not realistic. This called for a theory which combined the best of both worlds. In this subsection a step is made in this direction by introducing the additional filter on the access to the knowledge stock.

3.1.5 INNOVATION, KNOWLEDGE AND ENTREPRENEURSHIP

In the previous sections I discussed different concepts of knowledge and innovation and the process between them. I also related this to economic growth. I identified the theory of the Knowledge Spillover Theory of Entrepreneurship as a theory which makes the link between economic growth and innovation explicit by introducing the entrepreneur as an agent of change in their model. These following two subsections elaborate further on the role which entrepreneurs play in creating innovation. The first part will focus on the role that entrepreneurs play in the conversion process. The second part focuses on the degree of innovativeness of entrepreneurs.

3.1.5.1 THE ROLE OF ENTREPRENEURS FOR INNOVATION

Innovation and entrepreneurship, like innovation and knowledge, have been viewed as overlapping notions in the past. This can be traced back to Schumpeter's (1934) definition of entrepreneurship namely that creating new combinations (*e.g.* innovations) is equal to what the entrepreneur does.[28] In the process of innovation, the entrepreneur is the one who commercializes the invention. The inventor is a separate person, coming up with a new idea. Next to the entrepreneur and the inventor, Schumpeter names the capitalist, who provides the financial resources as well as a bearer of risks, and the manager, who runs the daily operations. From this quote, it is clear that Schumpeter sees the creation of an opportunity by the inventor as a separate factor. The entrepreneur is only there to utilize the invention:

> ***"It is no part of his function to 'find' or to 'create' new possibilities. They are always present, abundantly accumulated by all sorts of people. Often they are also generally known and being discussed by scientific or literary writers. In other cases, there is nothing to discover about them, because they are quite obvious."***
> ***(Schumpeter, 1934, p. 88)***

Important is to realize the difference between invention and innovation and that even though inventions can take place anywhere (for example, in a garage box by two friends with a passion for computers), the real innovations mostly occur in firms. This is because changing an invention, or knowledge, into an innovation takes skills. You also need knowledge, capabilities and resources. You might also need a distribution system or a factory. These are typical requirements which firms can fulfill (Fagerberg, 2004). However, having the resources is not enough; in order to be able to identify the valuable knowledge and to innovate one requirement should be fulfilled by the organization: the existence of absorptive capacity. This absorptive capacity is *"The ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities."* (Cohen & Levinthal, 1990, p. 16). This absorptive capacity holds for internal and external knowledge. Cohen & Levinthal (1989; 1990) found that research and development activities within the firm also have a key role: R&D not only allows the firm to generate innovations but also to identify, assimilate and exploit the knowledge spillovers. Incumbents which possess this ability help to enable spillovers: they learn from the new knowledge and internalize it further after which they commercialize it (Carlsson *et al.,* 2009). A downside for large incumbents is however that they cannot adapt easily to changes in the system. They have a certain set-up of their production process which is tailored in order to reach their targets. These are based on routines that have been in place for a while making adjustments costly and cumbersome (Christensen, 1997). A result might be that the really radical innovations are left aside by the large incumbents. In the literature this is

[28] See the previous chapter for the five different types of new combinations which entrepreneurs could provide according to Schumpeter (1934). This is an alternative way to classify innovations: according to one of these five types.

sometimes denoted with the term *"inertia"* or *"organizational inertia"*: the tendency of an incumbent or other mature organization to not change but continue on its current trajectory (Gilbert, 2005).

The lack of commitment and intent by large firms to innovate in a radical, Schumpeterian way provides room for the new ventures. Research shows that they are more likely to use radical innovations to get the competitive advantage they need in their battle against existing or large firms (Casson, 2010; Baumol, 2004b). These radical innovations will be particularly coming from entrepreneurs which have good access to knowledge spillovers (Braunerhjelm, 2010). These are the firms which play the decisive role in the knowledge-based economy of today, leading to the expected growth. Even though they usually have a lower absorptive capacity, entrepreneurs can play their large role in innovation. Because these entrepreneurs are motivated and alert to profit opportunities they are able to select the best part of the existing knowledge (Kirzner, 1979). They also have the different skills which an entrepreneur needs to survive: the high uncertainty, asymmetries in information and high transaction costs which are ultimately associated with knowledge will create a different point of view for people. These entrepreneurs have to ability to work with that. Everyone will have a different assessment or evaluation of the expected and possible value of ideas. As a consequence, the ability to commercialize knowledge will also differ across individuals, meaning that not all will become entrepreneurs. In conversing and diffusing the knowledge, they actively penetrate the knowledge filter discussed above (Acs & Plummer, 2005). By doing so they fulfill an additional requirement for increased competition and successive economic growth (Carlsson *et al.*, 2009; Braunerhjelm & Svensson, 2010). It is important to underline here again that the absorptive capacity theory is not limited to investments in R&D. Based on micro-level research, Freel (2003) finds that entrepreneurs produce knowledge not only through R&D but use also other function areas (*e.g.* collaboration partners). Shane (2000) finds evidence that small firms use other sources of knowledge than R&D. For instance, when the entrepreneur hears from the inventor directly who gives them the idea to start a company around it. He then receives the idea directly from the inventor without doing R&D himself.

Empirically, Acs & Audretsch (1987; 1988) found that small firms have a higher number of innovations per employee compared to large firms. They conclude that small firms thus have a greater innovative capacity. Others also find that even though the amount of R&D invested by the small firms is low, they have a substantial contribution to economic growth (*e.g.* Audretsch, 1995; Feldman & Audretsch, 1999).

Qian & Acs (2013) combine the idea of absorptive capacity with entrepreneurship as an important actor for knowledge spillovers. They argue that entrepreneurs not only work with or create new knowledge, but also use knowledge which was made in research institutes or incumbents. This is consistent with the presentation in figure 4. Their main argumentation is that the absorptive capacity of entrepreneurs is of a higher importance than new knowledge. This absorptive capacity is – in line with the ideas of Cohen & Levinthal (1989) – necessary for the entrepreneur to be able to actually use the knowledge. Their research, although mostly conceptual, brings entrepreneurship, spillovers and entrepreneurial absorptive capacity together for the first time. They empirically test this hypothesis with US data and find that absorptive capacity has a critical role within new firm formation. Their finding is consistent with Shane (2000) who also concluded on the importance of the existence of prior knowledge for the entrepreneur. This prior knowledge helps the entrepreneur to recognize opportunities. He could acquire this knowledge through prior work experience, personal events or education. This leads to the idiosyncratic character of prior knowledge (Venkataraman, 1997).

Empirically, Acs & Plummer (2005) tested the hypothesis that entrepreneurship – measured as new start-ups – is better in conversion of knowledge into economic knowledge than existing firms with their absorptive capacity. This hypothesis does not diminish the work of incumbents but rather investigates which vehicle that penetrates the knowledge filter has a stronger impact on economic growth eventually. They found evidence to support that new ventures – entrepreneurship – are better in penetrating the knowledge filter compared with incumbent firms. Another study, performed by Acs & Varga (2005), found a significant and highly positive effect of entrepreneurship on technological change. They also find that if an increase in R&D activities is not accompanied by an increase in entrepreneurial activity, the effect of this increase will be less compared to having support of a strong entrepreneurial base. Furthermore, Michelacci (2003) argues based on his theoretical model about the interaction between R&D on the one hand and entrepreneurship on the other. His model endorses the idea that entrepreneurship should increase with R&D efforts in order to allow for economic growth. He thus finds that if the capability to commercialize knowledge is absent (*i.e.* the knowledge filter is not broken) that economic growth might be absent to, even if R&D activity exists.

To summarize, the role of entrepreneurship is twofold. On the one hand do entrepreneurs play the role of creating innovations: they create knowledge by doing R&D activities. However, given that they only have a limited amount of investments in R&D activities, this role is small. Especially if we compare this with their other task, the exploitation of knowledge. They exploit existing entrepreneurial opportunities resulting from knowledge spillovers. As such I noted that entrepreneurs play a crucial role in turning knowledge into innovations. They use the knowledge that they received via the spillovers and turn them into innovations. This can be as a new firm (as in the Knowledge Spillover Theory of Entrepreneurship) but can also be within an existing firm (corporate entrepreneurship). Which mechanism is allowed also depends on the strictness of the definition of entrepreneurship, as I discussed in chapter two.

3.1.5.2 Degree of innovativeness of entrepreneurship

In the previous chapter, I narrowed the focus to innovative, Schumpeterian, entrepreneurs. I explained that entrepreneurship does not always equal small firms. We also recognized that not all entrepreneurship is innovative. Roughly, one can distinguish between innovative entrepreneurship and non-innovative or imitative entrepreneurship. The latter replicates other business while the former uses new, sometimes research-based ideas. Koellinger (2008) argues that our point of view determines if we view something as innovative entrepreneurship. When looking at the global level, something is less likely to be innovative than when we zoom into the regional level. An example is Starbucks[29]. Howard Schultz, the founder of Starbucks, got his idea for a coffeehouse in Italy. He recognized the coffee culture in Italy and saw that it could also play an important role in the social life of many Americans. He then introduced coffeehouses, adjusted for cultural differences in the US. This was an innovation in the US, they did not have it. However, on the global level, the concept turns out to be an imitation of Italian traditions. It should be made clear here that it is not automatically true that imitative entrepreneurship does not lead to economic growth at all. This depends on the stage of economic development of a country. The best example is China, where the spending on R&D is extremely low but the growth figures very high while for instance Japan forms a mirror image. This principle is also known as catch-up growth or the convergence theory. Catch-up is the movement towards the technological frontier (Kumar & Rusell, 2002). This frontier resembles all products possible considering the current state of technology. A country can thus make large steps towards this frontier by using imitative entrepreneurship. Minniti & Lévesque (2010) created a model were they set research-based and imitative entrepreneurship opposite to each other. Their model shows that if R&D has low returns and there are a high number of imitative entrepreneurs, growth is still possible. These entrepreneurs increase supply and competition which leads to growth. They reach this conclusion regardless of the ratio between imitative and innovative entrepreneurs or the low R&D expenditures.

Even when we limit ourselves to innovative entrepreneurship, as is the focus here, we should realize that they are not always the same in their output. And, with the assumption that only innovative entrepreneurship leads to growth, one could argue that the degree of innovativeness is a crucial question for development. Schumpeter's focus lies purely on radical innovations (Henderson & Clark, 1990); from empirical evidence, we know that only five percent of firms actually create radical innovations (Baumol, 2004a). Hence, it is good to consider this while designing the framework between entrepreneurship and economic growth. This subsection therefore aims to provide a short introduction into this area and provide some factors that should be taken into account.

Plenty of literature has studied the success factors for small firms when discussing innovations. The studies look at different characteristics which may concern the firm and market but also the innovation process to see

[29] See also Stam (2008) for the context of Kirznerian entrepreneurship.

whether they influence origination of product innovations.[30] These studies do not specifically look into the degree of innovation or entrepreneurship but rather focus on innovations in small firms. The seminal work in this field is by Acs & Audretsch (1988; 1990) who found that the engine of innovation, in certain industries, were the small firms. They also found that R&D and skilled labor positively relates to the number of innovations.

Koellinger (2008) is among the first to offer some theoretical and empirical intuitions to answer why the degree in novelty varies. He finds that, on the individual level, high educational attainment, high self-confidence and unemployment have an influence. The idea of high education attainment is consistent with the literature which suggests that education and being a successful entrepreneur are positively related (*e.g.* Evans & Leighton, 1989; Reynolds, 1997; Van Praag, 2005). On the environmental level[31], entrepreneurs who operate in countries which are highly-developed are more likely to produce innovations than entrepreneurs in developing countries. The empirical evidence in the article also shows that there are strong differences between countries in the number of pure imitative entrepreneurs and innovative entrepreneurs. Koellinger sees this as evidence that not only individual aspects can fully explain these variations but other factors are crucial as well. For instance, others in the country should generate a substantial amount of commercializable, new knowledge for the entrepreneur to utilize (Koellinger, 2008).

Martinez-Román & Romero (2013) focus on product innovations in small businesses. They focus on the degree of novelty in products. In addition to the Koellinger article, they find that firms which introduce substantial innovations are usually led by entrepreneurs with a large intrinsic motivation. Furthermore, they also find that a business culture in which it is important to work together with others (research centers, universities) is crucial for substantial innovations and seems not relevant at all for incremental innovations.

Acs (2010) reviews the theoretical literature in the field of high-impact entrepreneurship (HIE). HIE is "*The study of the actions of individuals responding to market opportunities by bringing inventions to market that create wealth and growth."* (Acs, 2010, p. 165). This class of entrepreneurship is based on innovation and the results are Schumpeterian of nature. While the article also discusses individual traits of high-impact entrepreneurs, the focus is on the more aggregated level. First, it is stated that knowledge spillovers are helping HIE. The previously unexploited knowledge can be seen as an entrepreneurial opportunity (Shane & Venkataraman, 2000). The availability of this knowledge is key for the possibilities for innovation. Secondly, the discussion on strategic entrepreneurial behavior[32] is of interest. One of the main questions is to what extent HI-entrepreneurs are subject to institutional and cultural influences. In particular it is discussed that stringent intellectual property laws limit the opportunities for entrepreneurs to become really innovative.

What results from the discussion above is the conclusion that the degree and type of innovation differ among different types of entrepreneurship. When constructing the further economic framework, we need to keep this in mind when speaking about entrepreneurship. Most literature though focuses on the individual characteristics of the entrepreneur himself, thus only some different environmental, non-individual factors are named here.

3.1.6 Wrap-up

In the past section, it was shown that knowledge is key for innovation. It is the soil on which innovation grows. Also, we saw that to turn knowledge into innovations a filter applies in which the non-useful knowledge stays behind. I added one more layer to the theoretical basis of this filter, namely one representing access to the knowledge stock. This concept was further related to a discussion on IPR protection and incentives to innovate.

Different agents are involved in this transition process. I have argued that a big role exists for entrepreneurs in this field. I have also discussed how the knowledge spillover theory of entrepreneurship relates to the classic notion of knowledge spillovers and their role in growth models. I made an attempt to link both schools of thought

[30] See De Jong & Vermeulen (2006, table 1) for an overview of studies and which determinants they consider.
[31] This is the level considering all elements around the entrepreneur. It thus reflects more the country level.
[32] Research on the intersection between entrepreneurship and strategic management (Acs, 2010)

by introducing an additional knowledge filter, the open society filter. Further, I discussed the different economic growth models and their evolution during the past years. This chapter thereby serves as an introduction to the model discussed in the next chapter.

4 Deduction of the Research Question

4.1 Introduction

In this paper, the main emphasis lies on disentangling the relationship between economic growth and entrepreneurship. Previous chapters have focused on the concept of entrepreneurship on the one hand and on the concept of innovation on the other. From these chapters one obvious point is that a relationship between entrepreneurship and innovation is anticipated. The point of this chapter is to unravel the gap in the literature and formulate a corresponding research question.

This chapter is organized as follows. First, the gap in the literature is illustrated. Second, the corresponding theory is explained which will be used as a basis for the rest of the paper. Lastly, the research question and hypotheses are introduced.

4.2 Gap in the Literature

This research combines two streams of literature, namely innovation literature and economic growth literature while focusing on the factor entrepreneurship. It will research both the determinants of innovation and the role of entrepreneurship in creating innovations. On the other hand, the effect of entrepreneurship on economic growth will also be considered. Constructing one framework to research the interplay between entrepreneurship, innovation and economic growth is the main contribution of this thesis.

Innovation literature

Research on the determinants of innovation focused in the past mostly on the meso- and micro-level of the economy. The research questions were typically about why some firms were more innovative than others and what factors are necessary to achieve that. Others focused on explaining innovation for a certain industry. Another stream was research on the regional level, trying to explain why some regions produced more innovations than others or trying to find the reason of success of certain regions. Only a few of these studies actually focused on determinants on the country level, and if they did so, the majority only offered an analysis for one country. By using a cross-country panel, I address an empirical need in this field of research.

Another novel point here is the addition of entrepreneurship as an explanatory variable, an input, for innovation. By adding entrepreneurship to the equation, I can test the assumption of the literature that entrepreneurs help to produce innovations. For example, by breaking through the knowledge filter (*e.g.* Carlsson *et al.*, 2009; Acs *et al.,* 2004; Mueller, 2006). Now, a research gap exists between linking the theoretical role with which the literature provides us for entrepreneurship and the empirical research in the field of innovation (Braunerhjelm & Svensson, 2010). In general there is consensus on the role of entrepreneurs but empirical evidence is still lagging behind. I seek to research if entrepreneurs indeed transform knowledge into innovations. By doing so, I empirically test the link between the knowledge spillover theory of entrepreneurship[33] and empirical research on innovation.

Economic growth literature

The second central topic of this thesis focuses on economic growth. Innovation has been part of the growth literature for a long time, dating back to the first economic growth models of Romer (1990). For example, some studies on economic growth use research and development expenditures as a proxy for innovation in their analysis of economic growth (*e.g.* Audretsch & Keilbach (2004b)). The addition of entrepreneurship to these growth equations is still a relatively new field which can be discovered further.

[33] See the next subsection for an in-depth discussion of the Knowledge Spillover Theory of Entrepreneurship.

Estimating these relations again with different variables can add a robustness check to the results which were found so far. Here lies, with a novel dataset for a longer period, another opportunity for this paper.

SYNTHESIS

Even though these contributions to the literature are important separately, the true contribution of this paper lies in the first empirical test in which the two relationships are estimated simultaneously. This provides me with the opportunity to test both the direct and the indirect effect of entrepreneurship on economic growth, as shown in the following picture:

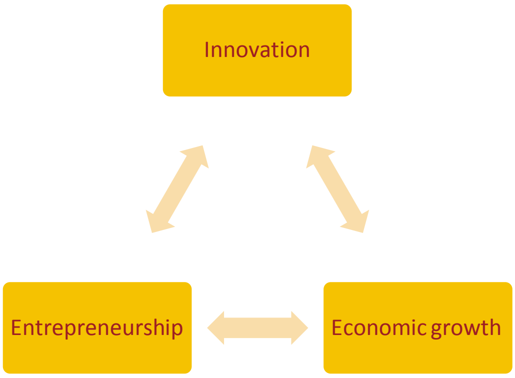

FIGURE 6: RELATIONSHIP ENTREPRENEURSHIP, INNOVATION AND ECONOMIC GROWTH

Figure 6 shows that entrepreneurship is expected to have a direct effect on economic growth, as well as to be an input factor for innovation. Innovation, in turn, has an effect on economic growth as well, hence the indirect effect of entrepreneurship. In the knowledge spillover theory of entrepreneurship, a crucial assumption is that entrepreneurs create new products (innovations) which results into economic growth. Hence, entrepreneurship is supposed to be an input factor for innovation. They are the mechanisms of change which is necessary for innovation to appear. From this, innovation itself contributes to higher levels of economic growth. Empirical studies so far have limited themselves to studying the direct effect by adding entrepreneurship to the growth equation (Van Praag & Van Stel, 2013; Acs, Audretsch, Braunerhjelm & Carlsson, 2012; Braunerhjelm *et al.*, 2010; Mueller, 2006). They have not yet modeled the step of entrepreneurship as a mechanism of knowledge transformation which is a central theme in the theory.

In this paper, I seek to explain the effect of entrepreneurship on the transformation of knowledge into innovation. Furthermore, I seek to explain the effect of entrepreneurship on economic growth. By estimating the two effects within the same model, I add to the literature by making the proposed link between entrepreneurship and innovation explicit. I do this by empirically showing that indeed there is a relationship between innovation and entrepreneurship and in a later stage economic growth. Also, I use a similar approach as existing studies which add entrepreneurship to the growth equation. If entrepreneurship also has an effect here, this might point into the direction of competition effects.

4.3 KNOWLEDGE SPILLOVER THEORY OF ENTREPRENEURSHIP

Theory has made the combination of innovation, growth and entrepreneurship a while ago. The most comprehensive theory is the knowledge spillover theory of entrepreneurship (KTSE) developed by Acs, Audretsch, Braunerhjelm & Carlsson in the first decade of the 21st century. This theory was already shortly introduced in chapter 3. Their theory consists of a two-step model in which entrepreneurship plays a crucial role. This model is the basis for the empirical approach of this paper. This subsection is dedicated to describing the model in detail. For this purpose, I build heavily on the paper *"The missing link: knowledge diffusion and entrepreneurship in endogenous growth"* (2010) by Braunerhjelm *et al*.[34]

The knowledge spillover theory of entrepreneurship can primarily be used to explain two different narratives. The first story is on knowledge, especially on how new knowledge which is not commercialized by incumbents or universities forms a source of entrepreneurial opportunities. The second story is the way that these opportunities are materialized, namely by the creation of new firms.

THEORY

The theory as a whole tries to build on the micro-economic basis of endogenous growth theory. Key is that opportunities for entrepreneurs are created endogenously in the model. This is the result of the central thesis of the endogenous growth models, namely that technological change is an endogenous variable. R&D activities of incumbent firms create these opportunities by creating new knowledge. This new knowledge is said to facilitate technological change. As stated before, knowledge is assumed to flow in the form of knowledge spillovers. A mechanism for these spillovers is lacking in the theory. The KTSE-theory answers this question, by adding the concept of transmission of knowledge spillovers by entrepreneurs. Entrepreneurs are there to identify (spot) the opportunities and exploit them into innovations. From this it follows that knowledge is reduced to a necessary condition, but not the only condition which has to be fulfilled to create economic growth. Thus, to summarize the main message of the theory: *"Entrepreneurship contributes to economic growth by acting as a conduit through which knowledge created by incumbent firms spills over to agents who endogenously create new firms."* (Acs *et al*., 2009, p. 17).

Question is then why entrepreneurship should be the conduit? The authors base their explanation on the characteristics of new knowledge. This new knowledge originates from existing organizations: incumbents, research institutions or universities. Intrinsically, new knowledge is considered to have a greater uncertainty and asymmetry compared to other economic goods. Using the agent as a unit of observation, one can reason from the preferences of that agent. Each agent will have a different mean expected value and variance about the new good. The new knowledge will thus be judged differently by different economic agents (Arrow, 1962a). The incumbent creator of the knowledge will thus have a different appreciation than another agent might have. This means that even if the incumbent decides not to pursue the new idea/good based on the expected economic value, this does not mean that another agent will also find the value too low to pursue. These agents might assign a higher value or have a lower minimum requirement. These other agents can be part of the incumbent firms but this is not a necessary condition. If someone from inside the firm decides to pursue the opportunity outside the firm, this is a case of corporate entrepreneurship. If another agent might decide to enter the market and appropriate the knowledge, a new entrepreneur emerged. It is thus assumed that the entrepreneur is not the inventor, but the innovator, in line with Schumpeter's theory (Schumpeter, 1934). This entrepreneur has a rare set of skills and insights which allows him to identify the opportunities. These skills are necessary: most opportunities are not presented as neat packages. In order to actually make the new product, development and commercialization is necessary.

Two assumptions are important to mention here: the model assumes that knowledge spillovers occur in the same period (*intra-temporal*). Traditional endogenous growth models assume *inter-temporal* spillovers. Second, there is a distinction between economic knowledge and all knowledge. This means that the level of spillovers is lower. This is in line with the concept of the knowledge filter as was discussed in the previous chapter. Another important assumption related to knowledge is monopolistic competition. Because knowledge is appreciated differently by different economic actors, certain heterogeneity is created. Only the ones who receive the knowledge and dare to turn it into economic knowledge will create a firm with that innovation. This

[34] This section only provides the key insights and equations from the model. For an in-depth discussion see the mentioned article.

heterogeneity is necessary for monopolistic competition. In short, firms compete against each other by using differentiated products.

MODEL[35]

The model assumes two methods through which new products can be developed: incumbents and entrepreneurs. Incumbents have research laboratory's in which they develop their inventions. Entrepreneurs create innovations. New products are final goods sold to either producers or consumers[36], in line with Romer's original work (1990). The goods are produced on a market which is characterized by monopolistic competition. This means that the stock of the new product is never exhausted and that there is an infinite flow of profits.

The first step in the model is to link entrepreneurs to the exploitation of knowledge. Second, is the knowledge production in the economy. Third is the endogenous growth model with knowledge-exploiting entrepreneurs.

ENTREPRENEURS AND KNOWLEDGE EXPLOITATION

Researchers are the creators of the new knowledge opportunities. One assumption of the KTSE model is that researchers work in incumbent firms. The assumption is that they have L_R employees. This is thus the labor factor for the research sector in the model. Another assumption is that labor is the only input factor in the research sector. Two factors further influence the production of knowledge: the efficiency parameter σ and the existing knowledge stock A. The efficiency parameter is a combination of factors which express how efficient the economy deals with the available production factors. Following the original Romer model, they do not distinguish between researchers in the business sector and in the universities/research institutions. Also, they assume constant returns to scale for simplicity reasons. From the signs, one sees that knowledge is positively related to production: more available knowledge means a higher technology output. Also, a higher efficiency level is positively associated with production.

$$Z_R(L_R) = \sigma_R L_R A \tag{1}$$

$$Z = Production\ function\ of\ a\ new\ technology$$
$$L_R = Number\ of\ researchers$$
$$\sigma = Efficieny\ level\ of\ the\ economy$$
$$A = Aggregated\ knowledge\ stock$$

Second is the production function of the entrepreneurs:

$$Z_E(L_E) = \sigma_E L_E^{\gamma} A, \qquad \gamma < 1 \tag{2}$$

$$Z = Production\ function\ of\ a\ new\ technology$$
$$L_E = Number\ of\ entrepreneurs$$
$$\sigma = Efficieny\ level\ of\ the\ economy$$
$$A = Aggregated\ knowledge\ stock$$

The set-up is similar to the research industry. They assume that entrepreneurial ability is shown in labor, hence the L_E. However, it is not just labor, they assume that it is unevenly distributed among the population, meaning that not everybody is gifted with the same level of entrepreneurial ability. This is shown by value of γ which is smaller than 1, denoting decreasing returns to scale for the number of entrepreneurs. This can be interpreted as entrepreneurs who make different combinations of labor and the available technology. At a certain point, an additional entrepreneur does not offer a large contribution towards the production. They thus use different production technologies from researchers yielding the decreasing returns to scale. Doubling the number of

[35] The first step of the model is the occupational choice of the individual to become an entrepreneur. This step is, although an integral part of the literature, less relevant for this thesis. For a thorough discussion, see Braunerhjelm *et al.,* (2010).

[36] Romer's original work assumed that the new products would be sold to final good producers. Grossman & Helpman (1991) showed that one can also think of these goods as sold to consumers without changing the outcomes of the model.

entrepreneurs does not yield a doubling of new knowledge output. Further, the set-up is equal: entrepreneurs use existing knowledge to produce. Their results are also influenced by the efficiency level of the economy. It is important to notice that entrepreneurs do not engage in research: they purely use existing knowledge and turn this into new combinations.[37] The capital goods produced by entrepreneurs can be thought of as *"As either a new type of physical capital, blueprints/patents or ''business models'' that can be used in the section of the economy producing final goods."* (Acs *et al.*, 2012, p. 291).

Entrepreneurs produce different varieties of capital goods. I further denote a product with x_i where i can range from $1 \dots j$. These capital goods can be thought of as for example new inventions or new varieties of products. The goods produced by the entrepreneurs on the one hand and the researchers on the other hand are used in the final goods sector. This sector produces Y with the following production function:

$$Y = (L - L_E - L_R)^{\alpha} \int_0^A x(i)^{1-\alpha}\, di\,, \qquad 0 < \alpha < 1 \tag{3}$$

$Y = Final\ good$
$L = Total\ population$
$L_E = Number\ of\ entrepreneurs$
$L_R = Number\ of\ researchers$
$\alpha = Scale\ parameter$
$x_i = Capital\ good\ j$

The production function has two different input factors: labor and capital goods. α is a so-called scale parameter. This means that it represents the relative importance of the production factors. If α is high, labor is relatively more important than capital. If α is really small, is production almost entirely based on capital goods. The range of the integral is between 0 and A. This indicates that technology determines the amount of capital goods which can be produced. The number of products possible is thus limited by the knowledge which is available. The population, L, is assumed to be constant.

I can rewrite this equation with the assumption that demand in the equilibrium state of the economy is equal for all varieties. This means that $x_i = \bar{x}\ for\ all\ i \leq A$. This means that I can rewrite the third equation as follows:

$$Y = (L - L_E - L_R)^{\alpha} A \bar{x}^{1-\alpha}, \qquad 0 < \alpha < 1 \tag{4}$$

This gives the equation for the final good production. I can now further assume that the technology used for final goods Y, is the same as the technology used for capital goods x. Now I can also assume that except for knowledge, we also need capital in order to produce the capital goods which the final goods sector uses. This can be shown in a formula as follows:

$$K = kA\bar{x} \tag{5}$$

$K = Capital\ stock$
$k = Units\ of\ capital\ goods\ to\ produce\ one\ unit\ of\ capital$
$\bar{x} = capital\ good$

[37] To illustrate this, please recall the Starbucks example in chapter 3. Starbucks' founders used the existing knowledge about coffee shops from Italy to set-up a sort like concept in the United States.

Combining equations (4) and (5), the final goods production function can be written as follows:

$$Y = (L - L_E - L_R)^{\alpha} A^{\alpha} K^{1-\alpha} k^{\alpha-1}, \qquad 0 < \alpha < 1 \tag{6}$$

Intermediate steps

$$Rewriting:$$

$$\frac{K}{kA} = \bar{x} \rightarrow \bar{x} = K * \left(\frac{1}{kA}\right)$$

Intermediate steps

Leaving $(L - L_E - L_R)^{\alpha}$ I can rewrite the second part of this equation.
First, let's fill in the value for $\bar{x}$:

$$A * K^{1-\alpha} * \left(\frac{1}{kA}\right)^{1-\alpha} =$$

$$A * K^{1-\alpha} * ((Ak)^{-1})^{1-\alpha} =$$

$$A * K^{1-\alpha} * A^{\alpha-1} * k^{\alpha-1} = A^{\alpha} K^{1-\alpha} k^{\alpha-1}$$

From this formula (6) it is clear that the economy has three separate production factors: labor, knowledge and capital goods. These last two are produced by entrepreneurs and researchers. In equilibrium, all labor in the economy should be when everybody is employed. This means that the following equation for the total population must hold:

$$L = L_F + L_R + L_E \tag{7}$$

$L = Total\ population, assumed\ constant$
$L_F = Total\ number\ of\ laborers\ in\ the\ final\ goods\ sector$
$L_E = Total\ number\ of\ entrepreneurs$
$L_R = Total\ number\ of\ researchers$

Knowledge production in the economy

The next step in the model is to explain the knowledge production in the economy. We saw before the researchers and entrepreneurs produce the new knowledge together. I can also show this in the function which explains growth in technology.

$$\dot{A} = Z_R(L_R) + Z_E(L_E) = \sigma_R L_R A + \sigma_E Z(L_E) A \tag{8}$$

$\dot{A} = Change\ in\ aggregated\ stock\ of\ knowledge$
$Z = Production\ function\ of\ a\ new\ technology$
$\sigma = Efficiency\ parameters\ in\ R\&D$
$L_E = Total\ number\ of\ entrepreneurs$
$L_R = Total\ number\ of\ researchers$

Growth in technology is thus due to the labor efforts by entrepreneurs and researchers, as well as current technology and the efficiency of the economy, as was shown in equation (1) and (2). This produced knowledge will also be available for others in the economy, in order to create future capital goods. Thus, current technology (knowledge) has a positive impact on future technology. This is what equation (8) expresses.

From this formula, we can also estimate the growth rate of technology, namely $\dot{A}/A$, by substituting equations (1) and (2).

$$\frac{\dot{A}}{A} = \sigma_R L_R + \sigma_E L_E \tag{9}$$

$\dot{A} = Change\ in\ aggregated\ stock\ of\ knowledge$
$A = Current\ stock\ of\ technology$
$\sigma = Efficieny\ level\ of\ the\ economy$
$(knowledge\ efficiency\ of\ investments\ in\ R\&D)$
$L_E = Total\ number\ of\ entrepreneurs$
$L_R = Total\ number\ of\ researchers$

From this, we see that the speed in which the economy can progress in the field of technology is an increasing function from the number of entrepreneurs and researchers, as well as how efficient they are at their job.

ENDOGENOUS GROWTH MODEL WITH KNOWLEDGE-EXPLOITING ENTREPRENEURS

The third step from the model is to create the endogenous growth model with knowledge-exploiting entrepreneurs. For the exact derivation of these steps, I refer to the original paper of Braunerhjelm *et al.* (2010).

Key is to mention the relevant drivers of economic growth, which should also be present in the empirical application of this model in this thesis. First, as was shown above, L_R are incumbents – researchers – which undertake R&D activities. This is the first process through which economic growth is created. The second is the opportunities for the entrepreneurs, which are created because not all potential opportunities are exploited to a full by the incumbents. These opportunities allow entrepreneurs to start new firms to exploit the knowledge (commercialize) and hence create a 'new version' of the knowledge. By influencing the stock of knowledge in this way, entrepreneurs ultimately also create growth.

The further step in the model is to combine equation (2) (production of knowledge by the entrepreneur) and equation (8) (technological progress) with two other problems. The first is making a combination with a consumer optimization problem, in order to express customer demand for final goods in the model. The second is the production function for final goods (see equation (6)). By combing the problem and solving it[38], it yields that economic growth depends on a set of parameters.

$$g = f(A, R, E, \lambda) \qquad (10)$$

$$\begin{aligned} &A = Current\ stock\ of\ technology \\ &R = Expenditures\ on\ R\&D \\ &E = Level\ of\ entrepreneurship \\ &\lambda = All\ other\ factors\ which\ influence\ growth \end{aligned}$$

From the equation it yields that economic growth depends on the available technology, investments in R&D, and the availability of entrepreneurship capital. These parameters all have a positive influence on economic growth. λ can be viewed as a residual category, it contains all other factors which can possibly affect economic growth besides R&D, technology and entrepreneurship. With the previous equations in mind, one can think of factors like supply of capital (K) or labor (L). From the theory chapter, it is clear that other factors like IP protection or education can also be relevant.[39]

Some implications can be derived from the model:

- In the steady state growth will increase if entrepreneurship and R&D are increasing. From this the proposition follows that if a labor force (country) has a higher level of entrepreneurs (L_E is high), it will have a higher growth rate compared to countries with a lower level of entrepreneurial activity.
- Growth rates are influenced by multiple factors. This means that if a country has a low level of entrepreneurship, this does not necessarily means that growth is lower as well. This effect can be offset to some extent with investments in research and development.
- Reasoning backwards, I can deduct that the knowledge spillover theory of entrepreneurship entails that if there are greater investments in knowledge, the level of entrepreneurial activity is higher. This is because there are more opportunities which the entrepreneurs can fill. Literature has confirmed this effect. For example, Audretsch & Lehmann (2005) who find the associations between start-up rates and knowledge investments in regions.

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[38] See for this process Braunerhjelm, Acs, Audretsch & Carlsson (2010), pages 112-114.

[39] For example, keep in mind the knowledge filter theory. Here, institutions could create barriers which made it more difficult for knowledge to transform into economically useful knowledge.

4.4 RESEARCH QUESTION AND HYPOTHESES

After describing the gap in the literature, a model was selected which is suitable to build a research to fill this gap. After describing it carefully in the last subsection, I now arrive at the research question. This research question should incorporate the gap in the literature as well as an empirical application of the model.

What is the relationship between entrepreneurship, innovation and economic growth at the macro-level?

This question captures the direct and indirect effect mentioned before. These effects form the two hypotheses researched in this paper. The research question entails three sub questions:

What is the relationship between entrepreneurship and innovation?
What is the relationship between economic growth and entrepreneurship?
What is the relationship between economic growth and innovation?

The first and second subquestion form the question on the indirect effect. The third subquestion refers to the direct effect. They will be discussed and introduced separately below.

INDIRECT EFFECT

The indirect effect assumes that entrepreneurship causes/is related to innovation. In line with the theory[40], this means that entrepreneurs use existing knowledge to create new opportunities for new firms. They create new (economically valuable) knowledge, for example in the form of patents or in the form of new business models. In the KTSE-model, entrepreneurs are modeled as researchers. They can enhance innovation in two ways: facilitating knowledge spillovers on the one hand or help to penetrate the knowledge filter on the other. Both results enhance innovation and ultimately growth. Thus, the expectation is that entrepreneurship has a positive effect on innovation (see equation (10)).

The indirect effect further suggests that innovation has a positive effect on economic growth. This was represented in the model as a positive effect of R&D on economic growth. This basic presumption has been the basis of all endogenous growth models (*e.g.* Romer (1990); Aghion & Howitt (1992)). However, it is an imprecise measure because R&D does not equal innovative output. Therefore, the hypothesis is that innovative output has a positive effect on economic growth.

The indirect effect hypothesis can be summarized by the following figure, with the plusses showing a positive effect.

DIRECT EFFECT

Apart from innovation, entrepreneurship can have another effect on economic growth. This is what I refer to as the direct effect. The idea behind the direct effect is that entrepreneurship adds in other ways to economic growth than by only introducing innovations. One such way can be that when an entrepreneur enters the market

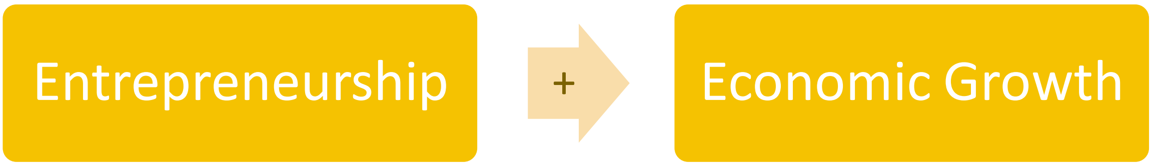
[40] For an extensive discussion of the relation between entrepreneurship and innovation, please see chapter 3.

this leads to increased competition. Another possible direct effect could be that entrepreneurs bring more diversity to the market.

The increased number of firms can lead to increased competition, which in turn results in a more efficient production (static efficiency). Kirzner (1997) already argued that entrepreneurship and competition may be viewed as synonyms of each other. Jacobs (1969) focuses on the competition which results from new ideas which are embodied in the new economic agents. This works in two ways: it allows competition for ideas (which can also help with the innovation part above) but also allows new firms to enter and work with their specific idea in a product niche. Empirical evidence was found by Feldman & Audretsch (1999) and Glaeser, Kallal, Sheinkman & Schleifer (1992). Both studies found evidence on the level of a city. They measured competition as the number of enterprises and found that an increase in the number of enterprises also increased the growth of that city.

Diversity is another possible direct effect. When more entrepreneurs enter the market, there is more choice for the consumer. This does not have to be competition per se; indeed a new firm can open a whole different market, offering a whole different good. In that respect, the new firm does not have to be a competitor of the existing firms. Again Glaeser *et al*. (1992) provided an empirical study, showing that diversity does indeed promote the growth of cities (measured in employment growth).

The direct effect is summed up in the following figure:



4.5 Wrap-up

This paragraph links the literature section of this thesis and the empirical part. It showed some areas in the literature which have not been researched extensively yet. This paper intends to make the first attempt to answer these remaining questions. Two clear contributions were identified. First, the thesis models the intermediate mechanism between entrepreneurship and economic growth by means of innovation. This allows research to verify if the relationship is indeed linear. A linear relationship was implicitly assumed in previous literature by modeling only the direct relationship between entrepreneurship and economic growth. Second, the distinction between innovative input and innovative output is clearly defined, using variables to represent innovative input and innovative output. Further, the (mathematical) model was described on which both hypotheses formulated in this paper were based. Both hypotheses as well as the research question were presented.

The next chapters will show the data, methodology and results of the empirical application.

5 MODELS

5.1 GENERAL

This thesis will focus on disentangling the relationship between entrepreneurship, innovation and economic growth. The question is, in other words, if there is a direct and/or indirect effect of entrepreneurship on economic growth. The indirect effect is via innovation. In order to do so, separate equations will be estimated using a dataset of 17 OECD countries for a 31 year time period.

In total, two equations will be estimated in one model each explaining part of the puzzle. One will estimate innovation and one will estimate economic growth. The innovation and economic growth equation are estimated to solve the model. In both equations entrepreneurship is used as one of the explanatory variables. A specific method is applied to solve endogeneity issues, as will be explained below.

This chapter is outlined as follows. First, I discuss the development of the equations which will be researched in this paper. Based on the theory which was discussed especially in the previous chapter, I select the relevant variables and discuss their contribution to this research. This approach allows me to discuss the details of these variables in the second part, the data section. I will discuss the definitions and sources of the data as well as some calculations. The last part is the methodology in which I will discuss specifics on the estimation methods. I use the equations developed in the first part as a guideline through that section. The methodology section contains information on techniques which deal with the specific demands caused by the simultaneous equation structure of this thesis. Also special attention is given to the panel structure of the data which also has its own demands. The wrap-up section concludes.

5.2 DEVELOPING ESTIMATION EQUATIONS

Based on the theory discussed in the previous chapters, several equations need to be estimated. I will use several equations in order to test the hypotheses between entrepreneurship and economic growth. The first equation represents the direct relationship between economic growth and entrepreneurship. It also helps to explain if there is an effect of innovation on economic growth. The second equation will represent the direct relationship between entrepreneurship and innovation.

MODEL 1: ECONOMIC GROWTH

I use a Cobb-Douglas production function for the estimation of the direct effect between entrepreneurship and economic growth. Based on this function I estimate the country-level economic performance on my panel of 17 countries between 1981 and 2011. For this method, see also the studies and approaches by Audretsch & Keilbach (2004a; 2004b), Fritsch & Schroeter (2011), and Mueller (2006). This approach to economic growth research forms a strand of literature, which uses a model of economic output as a function of several other factors. This approach has been used mostly for a comparison on the regional level within one country (*e.g.* Audretsch & Keilbach 2004a; 2004b), my contribution extends to the country level.

In Solow's theory (1956), he estimates the neoclassical production function also using a Cobb-Douglas function. His main input factors are, as mentioned before, capital (K) and labor (L). In Solow's model, technology was exogenous, represented by the A. In endogenous growth theory, an additional factor is added to this equation, namely knowledge. This is usually represented by Research and Development which is here denoted by R (Romer, 1986; 1990; 1994).Typically the production function then looks as follows:

$$Y = AK^{\alpha}L^{\beta}R^{\gamma} \tag{11}$$

In this equation, A is technology, K is physical capital, L is labor (total employment) and R is knowledge. The knowledge variable can be operationalized in different ways; most often is chosen to use research and development. I use a different approach, namely innovation output and not R&D or other innovation inputs. This is because not all R&D leads to innovation output, while it is innovative output which ultimately influences economic output (Y). Another reason is that I want to understand in the second equation what role entrepreneurship plays in creating innovative output. I view entrepreneurship then as an innovative input. In order to avoid confusion with the theory, I replace the R from the previous equation with an I. For estimation purposes[41], the model can be rewritten from equation (11) to equation (14). Equation (13) and (14) show the intermediate steps.

$$\frac{Y}{L} = AK^{\alpha}L^{\beta-1}\left(\frac{L^{\alpha}}{L^{\alpha}}\right)I^{\gamma} \tag{12}$$

$$\frac{Y}{L} = A\left(\frac{K}{L}\right)^{\alpha} L^{\alpha+\beta-1}I^{\gamma} \tag{13}$$

$$\ln\left(\frac{Y}{L}\right) = \ln A + \alpha \ln\left(\frac{K}{L}\right) + (\alpha + \beta - 1)\ln(L) + \gamma \ln I \tag{14}$$

From this equation, it is important to note that the estimation using regression software will estimate the value for $(\alpha + \beta - 1)$. A calculation is thus needed to find the true influence of labor, *i.e.* parameter β.

Additionally, Audretsch & Keilbach (2004a) were among the first to add entrepreneurship as a production factor to this model. I augment the production function in a similar way, namely:

$$\ln\left(\frac{Y}{L}\right) = \ln A + \alpha \ln\left(\frac{K}{L}\right) + (\alpha + \beta - 1)\ln(L) + \gamma \ln I + \delta E \tag{15}$$

Here, E stands for entrepreneurship or entrepreneurship capital. This is later operationalized in the form of the business ownership rate (percentage). Audretsch & Keilbach (2004a) themselves use a different measure: the number of new firm start-ups. They base their selection on the assumption that entrepreneurship is about newness, about starting a new firm. The measure selected here[42] (as will be explained below) is static of nature, being the number of business owners expressed as percentage of the labor force. This measure includes both the new and existing business owners. This measure is more consistent with the occupational choice theory compared to the behavioral notion of entrepreneurship.[43] One reason, and most important, for selecting this measure originates from data restrictions. The business ownership rate is one of the few measures that are available for a large number of countries over a large period of time and thus allowing the kind of analysis as proposed here. The second reason is that the measure can also be justified based on the KTSE-theory because also in this theory the micro-economic foundations originate from the choice of the entrepreneur (scientist) to own and manage a new firm with his available knowledge instead of staying an employee.

Additional to entrepreneurship, I add a fifth variable to the equation, namely education. Van Praag & Van Stel (2013) also added this variable to the Cobb-Douglas production function, as well as the business ownership rate. I add education for several reasons. First, education corrects for the level of development in a country. It is safe to assume that countries which are more developed have higher levels of education. Second, it shows how skilled the labor force is. Another way, next to innovation, used in the literature to endogenize technological progress in endogenous growth models is therefore human capital (*e.g.* Lucas, 1988). Human capital is believed to be very important in creating innovations. It is well possible that countries which grow faster are also endowed with a higher level of human capital (Grossman & Helpman, 1994). Education forms the operationalization of human capital in this paper. Another reason to include education has to do with entrepreneurship. Education is one of the most important drivers of (successful) entrepreneurship. This suggests that those entrepreneurs with higher levels of education are able to appropriate the entrepreneurial premium and are thus more successful as

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[41] See also section 5.4 on "Methodology". This measure is chosen to deal with the high correlations between the variables.

[42] See also section 5.3 on "Data".

[43] See also chapter 2 "Entrepreneurship" on this topic.

entrepreneurs. One explanation is that for business owners (or entrepreneurs) the appropriability of personal ability is higher (Van Praag, Van Witteloostuijn, & Van der Sluis, 2013). A proposition based on this is that at the country level higher levels of education result into higher levels of productive entrepreneurship. This in turn entails a stronger, closer relationship between entrepreneurship and economic growth. The higher levels of productive entrepreneurship should not be confused with higher levels of overall entrepreneurship. Entrepreneurs will have larger advantages from their education because it will allow them to build a larger company. This will lead to larger firms on average, which translates in a lower level of entrepreneurship (business ownership). Van Praag & Van Stel (2013) find that for countries with higher education rates have a stronger relation between productivity and entrepreneurship (measured as the business ownership rate), which shows support for this proposition.

Combined, the equation to be estimated is as follows:

$$\ln\left(\frac{Y}{L}\right) = \ln A + \alpha \ln\left(\frac{K}{L}\right) + (\alpha + \beta - 1)\ln(L) + \gamma \ln I + \delta_1 E + \delta_2 Education \qquad (16)$$

It is not necessary to take the logarithm because entrepreneurship and education can be seen as qualitative inputs in the production function (rather than quantitative inputs). The quantitative inputs represent the production factors for the production function. The constant returns to scale (CRS) assumption yields that the sum of the estimated elasticities for K, L & I should be around 1, hence not differ significantly from unity. The other variables, entrepreneurship and education represent the context of the economy. Besides, the variables are measured in percentages instead of absolute numbers.

In order to estimate the equation, a constant and an error term are added to the equation and the coefficients are renamed, including terms referring to the panel nature of the data:

$$\ln\left(\frac{Y}{L}\right)_{it} = \alpha_i + \beta_1 \ln(I)_{it} + \beta_2 \ln\left(\frac{K}{L}\right)_{it} + \beta_3 \ln(L)_{it} + \beta_4 E_{it} + \beta_5 Education_{it} + \varepsilon_{it} \qquad (17)$$

The parameter A is included in the constant, α_i. The β_2 represents the elasticity of capital intensity. Capital intensity is the amount of capital per worker. β_3 is the parameter for the labor variable, which is the equal to $(\alpha + \beta - 1)$. This labor term is included to be able to test the deviations from constant returns to scale with respect to capital and labor $(\alpha + \beta = 1)$, which is represented with β_3. β_1 represents the output elasticity of innovation, while β_4& β_5 represent the impact of entrepreneurship and education respectively.

One note should be added to this equation: rather than estimating the equation in growth rates (Δ), I estimate the equation in levels. Levels are able to capture the difference in economic performance in the long-run, while growth rates are more transient. The differences in the long-run are more related to welfare, which is the ultimate goal of enhancing by economic growth (Hall & Jones, 1999, p. 85). The second reason to follow this argument is that the changes in the business ownership rate are very small over time. The rate evolves very slowly.

Model 2: innovation

The second equation is the equation on innovation. The starting point for this equation is the Knowledge Production Function as introduced by Griliches (1979; 1986). This framework is usually applied in analyzing regional innovations within countries. For example Jaffe (1989) and Anselin, Varga & Acs (1997) in the United States. The innovation equation looks as follows:

$$\ln\left(\frac{I}{L}\right)_{it} = \delta_i + \gamma_1 \ln(R\&D)_{it} + \gamma_2 E_{it} + \gamma_3 Education_{it} + \gamma_4 \left(\frac{Y}{L}\right)_{it} + \gamma_5 \ln(L)_{it} + \gamma_6 University\ industry\ relations_{it} + \gamma_7 \ln(IP\ protection)_{it} + \mu_{it} \quad (18)$$

In this equation, innovation is divided by the total labor force. This is done in order to control for the size of a country in terms of the working force. Thus, it is useful in order to control for differences in country capacities (Acs, Audretsch, & Feldman, 1994).

The term innovation here refers to innovation output. It represents what is left after the end of the innovative process. This is crucial because only then is it possible to try and explain what entrepreneurship does for innovation. This represents the idea of the knowledge filter: several inputs lead to innovation as an output. The other inputs here are first of all expenditures on research and development. R&D is generally believed to be the most important and clear input for innovation. All investments in knowledge are represented by this variable. It shows the innovation efforts in a region for a large part. The general hypothesis is that more R&D should lead to more innovative output. I thus expect a positive sign for γ_1, which represents the impact of R&D.

The second variable included is entrepreneurship. I include this variable to test the hypothesis that entrepreneurship is an important input for innovation. This also follows from the KTSE-theory where entrepreneurs are the agents who use the knowledge spillovers and select the economically valuable knowledge. They are the ones who ultimately start the new firm and add to economic growth by attempting to commercialize new knowledge. They use the opportunities provided by R&D investments by incumbents towards their own advantage.

Education is included to represent the general idea that when people are more educated they also create more innovations. I thus believe that education should have a positive effect on innovational output.

GDP per capita is included to control for macro-economic influences. This variable represents the stage of economic development. At lower levels of economic development, other factors are important than at higher levels. Economic growth will then be determined by factors like land or unskilled labor. After moving from this factor-driven stage, through the investment-driven to the innovation-driven stage, innovation becomes more important. In the last stage, the competiveness of the economy – and ultimately the economic growth – becomes more dependent on the economy's ability to adapt to changes in technology and the level of social learning (Porter, Sachs, & McArthur, 2002). Labor is included because, as was shown in the theory section, general labor is the main ingredient of innovation. Labor is a measure of the number of people involved. Together with the education variable, it represents the human capital inputs for innovation (Griliches, 1979).

Furthermore, I add a variable representing the relationship between universities and industries. Although the connection has been made many times in the literature, most empirical studies have not included the variable in the regression. The main idea behind this is that if the connection between universities as centers of research, and the firms, as knowledge incubators, is very close, more innovation outputs will follow. Empirical evidence for this idea has been provided in the regional spillover literature. They all found that spatial proximity between universities, research facilities and agglomerations leads to higher levels of production (*e.g.* Glaeser *et al.,* 1992; Jaffe *et al.*, 1993; Henderson, Kuncoro & Turner, 1995; Audretsch & Feldman, 1996; Anselin *et al.*, 1997). If both are closely related, spillovers can occur more easily. Firms will access the knowledge faster making sure that the more knowledge created at universities and research centers is used for innovations. In order to make the link with the literature discussed before, the concept of the knowledge filter is important. The close relations make the knowledge filter thinner. The knowledge created at universities is usually at a more abstract level than the knowledge which firms can use to create their new products or production processes with. Thus the knowledge should go through the filter to become useful and transformed. This filter thus forms the connection with this additional variable. A second connection with the literature is that it extends the KTSE-theory. I add the idea of universities creating knowledge, while the theory is focused on incumbents to produce it. Also, in KTSE-theory the emphasis lies on the entrepreneur who starts the new firm. Here, I assume that the existing firms are a mechanism as well where new knowledge is created and commercialized in line with the idea of entrepreneurial employees as introduced by Erik Stam (2013). The term *'entrepreneurial employees'* refers to the entrepreneurial activities of employees within established firms. The university-industry relations are then proposed as an additional, second mechanism. Empirical research is in favor of this idea, recognizing that strong bonds can increase the rate of innovation (Spencer, 2001; Cohen, Nelson & Walsh, 2002; Laurensen & Salter, 2004). This is also related to the concept of the European paradox, which I described in previous chapters. Particularly European countries have trouble commercializing the generated knowledge within research institutes and universities (European Commission, 2001).

From the discussion on the knowledge filter in the innovation chapter, I found that there is a theoretical trade-off in terms of advantages and disadvantages for economic growth of the strictness of IPR: incentive to innovate (appropriability of newly created knowledge) versus the access to the knowledge stock. Empirically, this is also something that should be reflected in the specification. In order to do so, I add an indicator into the equation which captures the strength of intellectual property protection in a country. Innovation output is then, among others, a function of intellectual property rights protection, the strength of the relation between universities and industry and lastly R&D. R&D measures the knowledge creation in a country, while the other two indicators both provide a proxy for the access to the knowledge stock in a country and knowledge spillovers in the classical sense.

5.3 DATA

To estimate the models expressed in the previous section, I use a dataset consisting of 17 OECD-countries over the period 1981-2011. The dataset consists of the following countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, United Kingdom and the United States. These 17 countries were selected based on data availability for the variables that were specified above. The beginning period of 1981 was selected based on the availability of innovation statistics. Both patents as well as R&D statistics first became widely available for a large set of countries starting in 1981. To summarize, the equations are generated for 17 countries over 31 years yielding 527 observations in total.

Below I will describe the data in more detail, including the definitions and the data sources for the model variables. A summary of this part is found in table 4. This table includes the description of the calculations made.

Output ($\boldsymbol{Y}$)
I measure Y, output, as announced before in levels. I use the Gross Domestic Product (GDP) in constant 2005 prices in US dollars. I use 2005 purchasing power parities in order to systemize the different currencies across all countries. It allows me to compare the different monetary units. Data is obtained from the *OECD National Accounts database.*

Innovation output ($\boldsymbol{I}$)
Innovation should be expressed by a proxy that represents innovation output. This posed one of the major challenges of this paper. I decided that patents could be an appropriate proxy and will thus be used here. Patents counts are easily available for a large number of countries and they are also often used when researching the innovation capacity of a country (Furman, Porter, & Stern, 2002). R&D, a measure which is also often used, is as stated above an input measure of innovation. When focusing on innovation, I stated in the theory that there should also be a commercialization part. Only when commercialization is appearing, do I count it as an innovation in my definition. This is also a criterion which is mostly used in countries when one tries to obtain a patent. There has to be *'commercial applicability'* (Hall, Jaffe, & Trajtenberg, 2001).
The second point of attention for patents is that the quality and requirements for patents can differ among countries. Each country has its own rules and requirements for applicants. This is also valid for the protection

which each country offers for a patent. One example is that in both South Korea and Japan an inventor has to apply for separated patents for each claim. This prohibition of grouping claims leads to a very large number of patents which in turn leads to possibly overstating the technology creation in those countries. Thus, when one wants to use patents as an indicator for a nation comparison study, it is preferred to use a measure for which all these requirements are the same. One option to do so is to use the patents which are registered with one specific patent institution. Although the propensity to patent in another country might be lower, I assume that the truly influential inventions are patented by the patent offices of the major economies in the world. This same assumption is the reason why different measures of technological capabilities of a country all use the patents granted by the United States Patent and Trademark office (Archibugi & Coco, 2005). One reason might be that the United States economy is still the largest and most technologically developed economy in the world at this point in time.

This leads to the selection of utilized patents from the United States Patent and Trademark Office (USPTO) as the proxy of choice. The United States namely requires from its patents that they are utilized. This means that they indeed must be useful. Next to useful, the invention should also be novel and non-obvious. Only an invention which meets the combination of these requirements is granted a patent (Cohen, Nelson, & Walsh, 2000). I use the number of patents granted by the USPTO, sorted to the country of origin of the first-named inventor and by the year that the patent is granted.

Capital (K)

The measure for capital is obtained from Berlemann and Wesselhöft (2012). They created a new dataset for aggregate capital stocks between 1960 and 2011 for 103 countries. They start with the World Bank's World Development Indicator database. From this database they take the Gross Fixed Capital Formation data. Then they estimate the yearly capital stocks with the perpetual inventory method. This method is based on the assumption that the capital stock in each year is a function of the net capital stock at the beginning of the period increased by the gross investment during the period and then decreased with the consumption of capital during that period. This deprecation (consumption) is assumed to be with a constant depreciation rate. They use a geometric pattern to estimate this depreciation rate (for the exact calculation, see Berlemann & Wesselhöft, p. 10-14).

The article provides the capital stock in 2000 US dollars with purchasing power parities. My variables are all expressed in 2005 US dollars with PPP. Therefore, I use the inflation ratio to calculate the 2005 values of the capital stock. Thus, the expression of GDP and capital are now both in 2005 US dollars, constant prices and PPP.

Labor (L)

For labor, I want to estimate the total labor force which is actually employed. Therefore, I define labor as the total labor force minus the number of unemployed. This expresses the labor input to the economy of both business owners and employees. The data on the unemployed have been taken from the *OECD Labor Force Statistics.* I use the harmonized unemployment rate. This rate has been corrected for definition differences between countries. For the data on the total labor force, I use the *OECD Main Economic Indicators* database.

Entrepreneurship (E)

As was shown in chapter two, entrepreneurship is a difficult to define concept. This also results in difficulty to find a variable which measures entrepreneurship or the entrepreneurial climate in a country. There are several measures which are used in the literature: business ownership rates, self-employment rates and numbers of new firm start-ups.

I use the business ownership rate (%). This is more a measure which is related to the occupational notion of entrepreneurship than the behavioral notion, as was argued above. Based on data availability I select this measure anyway. The measure has been widely used and acknowledged in the entrepreneurship literature. For examples of other articles that use this measure see Block *et al*., (2013) and Koellinger & Thurik (2012).

The measure of the business ownership rate is defined as the total number of business owners divided by the total labor force. The business owners include both unincorporated and incorporated self-employed and self-employment as their main occupation. The measure is broad, because it also includes owner-managers of incorporated businesses. In line with other articles, I exclude business owners in agriculture, hunting, forestry, and fishing industries. The source of this data is the *COMPENDIA* database of EIM.[44] For business ownership, the original source of the data is the *OECD Labor Force Statistics* database. These numbers are harmonized and adjusted for differences between countries and over time (Van Stel, 2005).

Education

Education is measured as the gross enrollment rate (%) of people in tertiary education. This measure is obtained from the *World Bank EdStats Query* database. It describes the number of students enrolled in tertiary education, expressed *as the number of pupils enrolled in tertiary education, regardless of age, expressed as a percentage of the population of the 5-year age group following on from the secondary school leaving age*. This measure is a measure which is most likely associated with productivity and chosen on those grounds (Vandenbussche, Aghion, & Meghir, 2006). Others, for instance Barro (1991) used the primary and secondary enrollment rate. However, my belief is that tertiary education is a better proxy for the skills which individuals have. The higher the number of students in tertiary education, the higher also the skills of the population are. Human capital is then more developed. This could lead to more innovation and more economic growth. This type of education is believed to be the most important for both academic and industry innovation activities (Ding, 2008).
Unfortunately, the data for this variable is not complete. Therefore, when necessary, interpolation based on the trend in the data is applied.

Research and Development $(\boldsymbol{R\&D})$

For Research and Development (R&D) I use the Gross Domestic Expenditure on Research and Experimental Development (GERD) from the *OECD Science, Technology and R&D* database, more specifically the *Main Science and Technology Indicators*. This measure covers all R&D carried out on national territory within a given year. These expenditures are in US dollars, constant 2005 prices and 2005 purchasing power parities. The database covers the OECD countries from 1981 onwards but contains some blanks during the beginning years for some countries (for example Australia). When necessary, interpolation based on the trend in the data is applied to fill up the gaps.

University-industry relations

This variable is measured by the percentage of higher education R&D which is financed by industry. This is thus the amount of money which the industry puts into the R&D which is done at universities and other higher education organizations. The thought behind this is that the closer the connection is, the higher the share of financing of the industry will be (Mueller, 2006). The industry can in that case work closely together with universities and invest in projects which have a high potential for commercialization. I take this measure from the *OECD Main Science and Technology Indicators* database. The choice for higher education institutions is made because firms use knowledge from universities more often compared to other research institutions (Laurensen & Salter, 2004).
Unfortunately, the data for this variable is not complete. Therefore, when necessary, interpolation based on the trend in the data is applied.

Intellectual Property protection

I discussed in the theory section at length the relationship between intellectual property protection and innovation. I discussed that there is a trade-off between access to the knowledge stock which can yield more opportunities for entrepreneurs seeking to benefit from knowledge invented by other firms (*i.e.* knowledge spillovers) but on the other hand can discourage inventors to invest in knowledge. Therefore, I add a variable to

[44] See www.entrepreneurship-sme.eu for the database. COMPENDIA is an acronym for COMParative Entrepreneurship Data for International Analysis. See Van Stel (2005) for more calculation details and an explanation of the harmonization methods.

the innovation equation. I use the Ginarte and Park index of Intellectual Property Rights (Ginarte & Park, 1997; Park, 2008). This index is available for every five year period, between 1960 and 2005. This index is the sum for five categories which are not weighted. These five categories are (i) extent of coverage, (ii) provisions for loss of protection, (iii) membership in international patent agreements, (iv) enforcement mechanisms, and (v) duration of protection. These categories all get a score between 0 and 1. The sum of these values together constitutes the index.

Overview

This table specifies the calculations and the way the variables are specified in the equation.

Variable	Description	Data source
Output/capital $\left(\frac{Y}{L}\right)$	Gross Domestic Product divided by total labor force; US dollars; 2005 constant prices; 2005 purchasing power parities. In the regression, the natural logarithm of this variable is taken.	OECD National Accounts;; OECD Labor Force Statistics
Innovation (I)	Number of patents granted by the United States Patent Office. Patents are assigned to the year that they have been granted and to the country of origin of the first named inventor. Within the first equation, I use the natural logarithm. Within the second equation, I use the natural logarithm of innovation divided by labor.	USPTO
Labor (L)	Labor is calculated by subtracting the number of unemployed from the total labor force in a country. In the regression, the natural logarithm of variable is taken.	OECD Main Economic Indicators; OECD Labor Force Statistics
Capital/labor $\left(\frac{K}{L}\right)$	Capital is the stock of physical capital expressed in US dollars; 2005 constant prices; 2005 purchasing power parities. Capital is divided by labor, which is defined as above. In the regression, the natural logarithm of variable is taken.	Berlemann & Wesselhöft (2012)
Entrepreneurship (E)	Business ownership rate; number of business owners divided by the total labor force. Excluding business owners in agriculture, forestry, hunting and fishing. Expressed in percentages.	COMPENDIA version 2011.1
Education	The number of pupils enrolled in tertiary education, regardless of age, expressed as a percentage of the population of the 5-year age group following on from the secondary school leaving age.	World Bank EdStats Query
Research and Development	Gross Expenditure on Research and Experimental Development (GERD) expressed in US dollars; 2005 constant prices; 2005 purchasing power parities. In the regression, the natural logarithm of variable is taken.	OECD Science, Technology and R&D
University-Industry Relations	The percentage of higher education R&D which is financed by industry.	OECD Main Science and Technology Indicators
IP Protection	Ginarte-Park Index for Intellectual Property Rights. Sum of five categories each scored between 0 and 1. (i) extent of coverage, (ii) provisions for loss of protection, (iii) membership in international patent agreements, (iv) enforcement mechanisms, and (v) duration of protection. In the regression, the natural logarithm of variable is taken.	Ginarte & Park (1997); Park (2008)

TABLE 4: DESCRIPTION OF VARIABLES

5.4 METHODOLOGY

5.4.1 SIMULTANEOUS EQUATION MODELS

In this thesis, simultaneous equation models are used. These are systems of equations in which one (or more, as in this thesis) of the dependent variables are used as an explanatory variable in the equation for the other dependent variable. The equations of the model describe the economic world; they are so-called structural form equations. If the equations have a meaning separately from each other – in isolation of the other equations in the system – the equation is called *autonomous* (Wooldridge, 2002a). The autonomy argument is closely related to causality. The idea is that each of the equations in the system is based on a causal relationship: this means that every equation should have a ceteris paribus, causal interpretation.

Before explaining the methodology behind solving this simultaneous equation model, it is important to explain why standard OLS[45] is not the appropriate method: it is biased and inconsistent. The reason for this is that the explanatory variable that is estimated simultaneously with the dependent variable is correlated with the error term. In order to show this mathematically, I simplify the equations to be estimated:

$$\ln I = \gamma_0 + \gamma_1 \ln\left(\frac{Y}{L}\right) + \gamma_2 Z_1 + \varepsilon_1 \tag{19}$$

$$\ln\left(\frac{Y}{L}\right) = \lambda_0 + \lambda_1 \ln(I) + \lambda_2 Z_2 + \varepsilon_2 \tag{20}$$

Here Z_1 & Z_2 denote the exogenous variables in equation (19) and (20). They are thus not correlated with the error terms ε_1 & ε_2. Exogenous in this context means that the variables only occur in one of the equations. To simplify the calculation, the intercept is suppressed. Now, to show the correlation between $\ln\left(\frac{Y}{L}\right)$ with the error term ε_1, the system of equations is solved for $\ln\left(\frac{Y}{L}\right)$. First, I can plug in the right-hand side of the innovation equation in the second equation:

$$\ln\left(\frac{Y}{L}\right) = \lambda_0 + \lambda_1\left(\gamma_0 + \gamma_1 \ln\left(\frac{Y}{L}\right) + \gamma_2 Z_1 + \varepsilon_1\right) + \lambda_2 Z_2 + \varepsilon_2 \tag{21}$$

$$(1 - \lambda_1\gamma_1)\ln\left(\frac{Y}{L}\right) = \lambda_1\gamma_2 Z_1 + \lambda_2 Z_2 + \lambda_0 + \lambda_1\gamma_0 + \lambda_1\varepsilon_1 + \varepsilon_2 \tag{22}$$

$$\text{Assume that } \lambda_1\gamma_1 \neq 1 \tag{23}$$

From equation (22) it can be derived that there is a relationship between $\ln\left(\frac{Y}{L}\right)$ and ε_1. One can see that they are in some way correlated with each other. The consequence is that in the equation (19) there is a correlation between the independent variable and the error term, between $\ln\left(\frac{Y}{L}\right)$ and ε_1. This thus means that we have *endogeneity*. The value of the variable is then determined within the system of equations rather than outside the model. This is a violation of the Gauss-Markov theorem leading to OLS being both biased and inconsistent (Greene, 2002). Gauss-Markov requires that the error term is not correlated with any of the independent (x) variables and states that the mean value of the error term (ε) is zero. If a variable which is on the right-hand side of the equation is endogenous, then it is correlated with the error term. This means that the mean value of the error term will not be equal to zero but higher or lower. This depends on the value of the endogenous variable. Not only the OLS estimates of the parameters are inconsistent and biased, this is also the case for the standard errors. The consequence is that inference of significance is rather difficult.

Of course, by doing the same exercise and solving for the first equation, one would find that there is a relation between innovation and the second error term. Hence, this equation as well does not meet the requirements

[45] In this paper, this would be pooled OLS due to the panel nature of the data.

for OLS. The problem discussed here is called the *simultaneity bias* (Wooldridge, 2002b). The simultaneity bias is a special type of the endogeneity problem.

From equation (22), I can go one step further to estimate the so-called *reduced form equation.*[46] Rewriting the equation by dividing the right hand side by $(1-\lambda_1\gamma_1)$ leads to the following form:

$$\ln\left(\frac{Y}{L}\right) = \pi_0 + \pi_1 Z_1 + \pi_2 Z_2 + \eta_2 \tag{24}$$
$$\pi_0 = \frac{\lambda_0 + \lambda_1\gamma_0}{1-\lambda_1\gamma_1}$$
$$\pi_1 = \frac{\lambda_1\gamma_2}{1-\lambda_1\gamma_1}$$
$$\pi_2 = \frac{\lambda_2}{1-\lambda_1\gamma_1}$$
$$\eta_2 = \frac{\lambda_1\varepsilon_1 + \varepsilon_2}{1-\lambda_1\gamma_1}$$

Equation (24) is written in the so-called reduced form. These π values are called reduced form parameters, while the λ & γ above are so-called structural parameters. η_2 is the reduced form error, while ε_1 & ε_2 are the structural errors. This form allows me to use OLS, however I can then only estimate the π values, which will not provide enough information on the structural and causal relationships which I want to estimate in order to answer the research question. OLS is allowed with these equations because there is no correlation between $\varepsilon_1, \varepsilon_2$ and Z_1, Z_2. This means that there is also no correlation between Z_1, Z_2 and η_2.

The most-used method to solve simultaneous equation models is the method of instrumental variables or two-staged least squares (Wooldridge, 2002b). Before this method can be applied, the requirement of identification has to be met. I discuss this requirement first. Second, I will discuss the method of two-stage least squares in general, for a system of simultaneous equations. Lastly, I will discuss the method in the case of panel data and simultaneous equations.

5.4.2 Identification

First, below we see again the estimated equations. It is visible that innovation and GDP per employee are the endogenous variables. Exogenous are R&D, education, university-industry relations, IP protection, labor, capital/labor ratio and entrepreneurship. They are determined outside the model.

$$\ln\left(\frac{Y}{L}\right) = \beta_0 + \beta_1 \ln\left(\frac{K}{L}\right) + \beta_2 \ln(L) + \beta_3 \ln I + \beta_4 E + \beta_5 Education + \varepsilon_2 \tag{25}$$

$$\ln\left(\frac{I}{L}\right) = \gamma_0 + \gamma_1 \ln(R\&D) + \gamma_2 E + \gamma_3 Education + \gamma_4 \ln\left(\frac{Y}{L}\right) + \gamma_5 \ln(L) + \gamma_6 University\ industry\ relations + \gamma_7 \ln(IP\ protection) + \varepsilon_1 \tag{26}$$

If you want to estimate a model using OLS, the requirement of identification has to be met. This means that each explanatory variable has to be uncorrelated with the error term. We saw that this condition is not met in this system of equations which makes it impossible to estimate the equations separately. Using instrumental variables solves this issue because it allows identifying or consistently estimating the parameters in the SEM equations. Statistically this means that we have to assume that these exogenous variables are not correlated with the error terms ε_1 & ε_2 (Wooldridge, 2002b). Having a model which is under identified also has the consequence that it is impossible to find an estimate for each parameter in the model. If it is identified, the model

[46] This type of equation will be used in the first stage of 2SLS.

can be estimated. I am now looking at both the *rank condition* and the *order condition* for identification of our model. The order condition is necessary but not sufficient; therefore one should also look at the rank condition.

- *Order condition:* This means that in order for the equation to be identified, the total number of variables excluded from the equation but included in the order equations of the system has to be equal or greater than the number of equations minus one (Gujarati, 2004). In the words of Wooldridge (2002b, p. 799): *"The total number of exogenous variables must be at least as great as the total number of explanatory variables."*
- *Rank condition:* When you have a system of X equations, any equation is identified if it is possible to create a determinant (not equal to zero) of the order X-1. You can use therefore the coefficients which are excluded from this equation but are present in the other equations of the system. In other words: *"The first equation in a two-equation simultaneous equations model is identified if and only if the second equation contains at least one exogenous variable (with a nonzero coefficient) that is excluded from the first equation."* (Wooldridge, 2002b, p. 510). This thus means that at least one of the exogenous variables in the first equation must have an influence on the population of the second equation. Thus, its parameter must not be equal to zero. In order to test this, an *F*-test or *t*-test has to be employed.

The rank condition is necessary to make sure that the exogenous variable which I want to use as an instrument (as I will discuss later) actually appears in the second equation. Looking at the two equations, I can state that both meet the order condition. The GDP/labor equation is identified if the R&D, university-industry relations or IP protection parameter has a non-zero coefficient in the innovation equation. For the second equation, the innovation function, it meets the order condition because one exogenous variable, the capital/labor ratio is omitted from the innovation equation. The rank condition is then that the capital/labor ratio has a non-zero coefficient in the first equation (GDP/labor equation).
In order to test these assumptions, I need to use the reduced form equations. By using the same method as before, the reduced form equations are the following:

$$\ln\left(\frac{Y}{L}\right) = \pi_{10} + \pi_{11}\ln(R\&D) + \pi_{12}E + \pi_{13}Education + \pi_{14}University\ Industry\ Relations + \pi_{15}\ln(IP\ protection) + \pi_{16}\ln(L) + \pi_{17}\ln\left(\frac{K}{L}\right) + \eta_1 \quad (27)$$

$$\ln\left(\frac{I}{L}\right) = \pi_{20} + \pi_{21}\ln(R\&D) + \pi_{22}E + \pi_{23}Education + \pi_{24}University\ Industry\ Relations + \pi_{25}\ln(IP\ protection) + \pi_{26}\ln(L) + \pi_{27}\ln\left(\frac{K}{L}\right) + \eta_2 \quad (28)$$

For the rank order condition to hold for the first equation $\pi_{17} \neq 0$ needs to hold. For the second equation, $\pi_{21} \neq 0\ or\ \pi_{24} \neq 0\ or\ \pi_{25} \neq 0$ needs to hold. Both should be tested with an F-statistic test. Hereby, I make the assumption that R&D, IP protection and University-industry relationship have no influence on GPD/labor, once the capital-labor ratio, labor, entrepreneurship and education are accounted for.

Once, the identification criterion is met, estimation of the model is possible with the two-staged least squares estimation method. In this method, the instrumental variables are the exogenous variables appearing in both equations.

5.4.3 Two-stage least squares for simultaneous equation models

Above I discussed the problem of not meeting the Gauss-Markov criterion and the consequences for OLS. One solution to this problem is offered by 2SLS. It involves making the assumption that for the endogenous variable there is another relationship between this variable and the dependent variable. In this case I use the fact that it is endogenous. Making this assumption implies that there is a second equation describing the relationship between the endogenous explanatory variable and the dependent variable. In abstract terms, this looks as follows:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + u \tag{29}$$

$$x_1 = \gamma_0 + \gamma_1 z + \gamma_2 x_2 + \cdots + \gamma_k x_k + v \tag{30}$$

In this example, x_1 is an endogenous variable. However, I assume that there is another relationship which can explain x_1. Here we see an additional variable which does not appear in equation (29). This is a so-called instrumental variable. z denotes the instrumental variable. An instrumental variable should have the following characteristics:

- It does not appear in the original equation
- It is uncorrelated with the error term in the first equation: the variable is exogenous. This can also be visualized as follows: $Cov(z, u) = 0$
- It is (partially) correlated with the endogenous explanatory variable. In other terms: $Cov(z, x) \neq 0$

The most difficult assumption is the lack of correlation between the error term and the instrumental variable. In order to do so, one should use common sense or economic theory. If this assumption is false, 2SLS as well provides inconsistent estimates. However, 2SLS can still be the preferred if the following condition is met:

$$\frac{Corr(z, u)}{Corr(z, x)} < Corr(x, u) \tag{31}$$

Two-stage least squares regression or 2SLS uses two different stages to estimate the equation. These stages are also visible in the simple example above. The first stage of the regression creates an instrument for the endogenous variable. This is the same as equation (30) above. This is done by running a regression where the endogenous variable is the dependent variable. All other independent variables in the regression are used as independent variables. With the results of this regression, you can predict a value for each observation.

In a system of two equations the independent variables are all independent variables which appear in both equations. Thus, these are the independent variables in the innovation equation as well as in the GDP/labor equation. In other words, the first stage uses the *reduced-form* equations in order to estimate the predicted values of the endogenous variables. The reduced form equations regress the endogenous variables on all exogenous ones. These predicted values are 'purged' from being simultaneous with the other endogenous variable because it is found using pre-determined variables. This first stage thus provides a solution for the simultaneity bias.

For a system of two equations we have – as showed in the subsection identification – two endogenous variables. This means that I need an instrument for both endogenous variables. I thus need to run the first stage equation two times, once with innovation as the dependent variable and once with GDP/labor as the dependent variable. I can use equations (27) and (29) for this stage. From these equations we see that different instruments are available for both. For the innovation function, the capital-labor ratio forms the instrument. For the GDP/labor function, R&D, university-industry relations and IP protection form the instruments.

Using these predicted values, the structural equation as explained above can be estimated. In this case the predicted values are used as one of the independent variables. The other independent variables are those which were originally hypothesized to be part of the structural equation ('causal relationship'). Thus, in basic terms not the original values of the parameters are used but the ones predicted in the first stage of the 2SLS procedure.

5.4.4 PANEL DATA

After describing the general thoughts behind 2SLS and what the conditions are for application, it is also necessary to take the special characteristics of the panel structure of my dataset into account.

A panel dataset has both a cross-dimensional and a time series dimension. Here, the same 17 countries are followed over a time period of 31 years. Panel data allows to research why the same units behave differently at different points in time. Problem with these two dimensions is that it also entails that the observations are not independent from each other. In the estimation method, one has to correct for this.

One method is fixed effects estimation; in simple terms the equation to be estimated then looks as follows:

$$y_{it} = \alpha_i + x'_{it}\beta + \varepsilon_{it}, \qquad t = 1,2,\dots,T \tag{32}$$

Here, i represents the cross-dimension and thus each i represents one country. t represents the time, thus each year. Here x'_{it} is a vector which includes all exogenous variables and ε_{it} is the error term. The assumption is that all x_{it} are independent of all ε_{it}. The α_i is the fixed effect. One can view this as a country dependent intercept. This method has as an additional advantage that it absorbs the unknown fixed factors which are not included in the regression. I can thus consider this a fixed unknown parameter. The advantage is that the probability of omitted variable bias is reduced by using this technique. It allows me to abstract everything captured in α_i from the error term, which solves some endogeneity issues.

One can also write this equation differently, with a dummy variable for each country i in the model:

$$y_{it} = \sum_{j=1}^{N} a_j d_{ij} + x'_{it}\beta + \varepsilon_{it} \tag{33}$$

The dummy takes the value 1 if $i = j$ and 0 if this does not hold. There are in total N dummies in the model. This is in my model the total number of countries involved, thus here it would be $N = 17$. This also entails that there are $\alpha_1, \dots, \alpha_N$ different intercepts. Both α and β can be estimated using OLS techniques. It can however be very unattractive to have to estimate a model with so many different dummies when one wants to know the value of β. A simpler way is as follows, where I eliminate all individual (country) effects in order to reach the estimates for the different independent variables in the model. I can take for each i the average over time:

$$\bar{y_\imath} = \alpha_i + \overline{x'_\imath}\beta + \bar{\varepsilon_\imath} \tag{34}$$

α_i is fixed over time and disappears in equation (35). We know that $\bar{y_\imath} = T^{-1}\sum_{t-1}^{T} y_{it}$, which is similar for all other variables included in the regression, using this knowledge I can write the model from equation (34) as follows:

$$(y_{it} - \bar{y_\imath}) = (x_{it} - \bar{x_\imath})'\beta + (\varepsilon_{it} - \bar{\varepsilon_\imath}) \tag{35}$$

This is a transformation of the model where one uses the observations in deviations from their means. This is called the *within transformation*. By doing so, the intercepts are deleted from the equation because they do not change over time. $\alpha_{it} - \bar{\alpha_\imath}$ is thus equal to 0. Now I can use pooled OLS techniques to estimate equation (35). Pooled techniques mean that we pool (combine) all observations for the same unit. The estimation which can then capture the correct value for β is referred to as the *fixed effects estimator* (Wooldridge, 2002b).

In essence, the fixed effects estimator focuses on the variation within the different countries. This helps us to explain the variation over time and why the observation of $y_{it} \neq \overline{y_i}$. It does not explain why countries are different from each other, thus not why $y_i \neq y_j$ (Verbeek, 2012). The advantage of this method is that it helps to conclude that the main findings hold irrespective of individual or country-specific effects.

5.4.5 Two-stage least squares for panel data

The models estimated here are estimated on the country-level. I can make a contribution to the literature by running the analysis on panel data. This allows me to use both dimensions, *i.e.* the cross-section and the time-series dimension. It was shown in the previous subsection that specific techniques are available for panel data. However, I also have to work with the specific type of model, *i.e.* a simultaneous equation model that I want to specify here. This subsection describes what this entails.

In order to estimate the models with panel data, I use a combination of the two methods described above: two-stage least squares and fixed effects estimation. To do so two steps need to be taken (Wooldridge, 2002b, p. 520):

1. Eliminate the unobserved effects of the equations using fixed effects transformation of first differencing
2. Find instrumental variables for the endogenous variables in the transformed equation

The fixed effects method brings with it the restriction that the variables which need to be found for the second step are time-varying. This means that all variables which do not change over time cannot be of any value in the estimation process. Luckily, all variables which are included in my simultaneous equation model are time-varying, although sometimes slowly.

In general terms, this procedure looks as follows. A simple example is used to illustrate this.

$$y_{it\,1} = \gamma_1 y_{it\,2} + z_{it\,1}\boldsymbol{\beta}_1 + \alpha_{i1} + \varepsilon_{it\,1} \quad (36)$$

$$y_{it\,2} = \gamma_2 y_{it\,1} + z_{it\,2}\boldsymbol{\beta}_2 + \alpha_{i2} + \varepsilon_{it\,2} \quad (37)$$

Here, $y_{it\,1}$& $y_{it\,2}$ are the endogenous variables. γ is the parameter for these endogenous variables and β for the exogenous variables. $z_{it\,1}\boldsymbol{\beta}_1$ & $z_{it\,2}\boldsymbol{\beta}_2$ are both simplified notations for the set of exogenous variables. They are thus linear functions of a set of explanatory variables. They represent $\beta_{11}z_{1t\,1} + \ldots + \beta_{1k}z_{1tk}$ etc. There are two sets of fixed effects, both denoted by α. This fixed effect makes that all exogenous (z) variables, as well as the endogenous variables – are correlated with these unobserved effects (α). This is not the case for ε, which is not correlated with z in both equations, and over all time-periods. This is why they are exogenous as we saw above. Together, α and ε form the composite error term. The problem in these equations is that both $y_{it\,1}$& $y_{it\,2}$ are endogenous and consequently correlated with the composite error terms. This means that on top of dealing with ε, which was discussed before, I also need to correct for the correlation with α. This is because the exogenous variables are now also correlated with the α part of the error term. This is why an additional step is necessary before performing two-stage least squares estimation: I need to make sure that the instruments can be used again.

The first step which I have to take is to use the fixed effects estimator to remove the α term from the equation (as we saw above in the section on fixed effects). The first equation subsequently looks as follows:

$$(y_{it\,1} - \overline{y_{\iota\,1}}) = (y_{it\,2} - \overline{y_{\iota\,2}})\gamma_1 + (z_{it\,1} - \overline{z_{\iota\,1}})\boldsymbol{\beta}_1 + (\varepsilon_{it\,1} - \overline{\varepsilon_{\iota\,1}}) \quad (38)$$

Now, again, the α terms are taken from the equation because they do not change over time. This leaves the variables which change over time. The result of this exercise it that now all exogenous (z) variables are not correlated with the error term anymore, by assumption. However, this leaves the y terms to still be correlated with the error term ε, just like in the pure cross-sectional version of this problem. In order to solve this problem, I use the exogenous variables as instruments. These are the variables which appear in the second equation but do not appear in the first equation as well. I explained which variables these are above and showed that this is the first stage. With the estimates of this first stage, the second stage equation is started. In this phase the structural equations can be estimated. In short, by using this methodology, I can now estimate the total model as detailed in the 'specification' section of this chapter. The results are in the next chapter.

5.5 WRAP-UP

In this section, the specifications of the model were introduced. First, the equations were introduced which will be estimated in the next chapter. These specifications were built upon the theory discussed in chapters 2, 3 and 4. Two different equations were designed together in a simultaneous equation framework, one explaining economic growth and one explaining innovation. In both equations entrepreneurship plays an important role. In order to estimate this framework several sources of data were appealed to. This leads to the construction of a panel dataset which consists of nine different variables. These variables are available over a time period of 31 years and 17 countries.

This framework makes that a combination of panel data estimation techniques as well as simultaneous equation model techniques have to be applied. In the methodology section it was stepwise explained why these techniques were necessary. The problems and potential solutions were discussed which lead to the selection of a two-stage fixed effects model. The next section will use this technique to estimate the specific equations with the selected data.

6 Results & Discussion

6.1 Introduction

This section forms the empirical heart of this paper. First, some descriptive statistics are provided on the included variables, which were introduced in the data section. Except for the standard statistics, special attention is given to the entrepreneurship variable. Second, the results are presented and discussed from the regressions on economic growth and innovation. Both equations are discussed separately and put into the perspective of the theory as discussed above. Lastly, some different specifications are provided to test the robustness of the results. The wrap-up concludes.

6.2 Descriptive statistics

In this section I provide descriptive statistics for all variables included in this paper. Both the correlations as well as the standard descriptive statistics of the variables are discussed. Additionally, I provide some numbers on the business ownership rate in the countries which are included in the research.

First, the descriptive statistics can be found in the following table:

Variable		Mean	Std. Dev.	Min.	Max.
Output (Y)	GDP (in mln. US$)	1343962	2439339	5194	1.38e+07
Labor	Total labor force (in 1000)	20029	31390	124	147279
Capital	Stock of capital (in mln. US$)	3930580	6768302	16158	3.65e+07
Output/labor $\left(\frac{Y}{L}\right)$	GDP per laborer (in mln. US$)	61322	12098	36236	98103
Capital/labor $\left(\frac{K}{L}\right)$	Capital per laborer (in mln. US$)	156253	47458	61638	340553
Innovation (I)	Total granted patents	6604	16825	17	108622
Innovation/labor $\left(\frac{I}{L}\right)$	Total granted patents per 1000 laborers	0.196	0.199	0.004	1.797
Entrepreneurship (E)	Business ownership rate (in %)	0.099	0.024	0.056	0.165
Education	Tertiary enrollment rate (in %)	0.515	0.193	0.164	0.971
Research & Development	Expenditures on R&D (in mln. US$)	32079	64331	33	374198
University-Industry relations	Higher Education R&D financed by industry (in %)	0.055	0.035	0	0.243
IP protection	Ginarte-Park index	4.079	0.609	2.12	4.88

TABLE 5: DESCRIPTIVE STATISTICS (N=527 FROM 17 COUNTRIES OVER 31 YEARS)[47]

We see that the mean of output per laborer is equal to US$ 61,321 with a range between US$ 36,236 and US$ 98,103. The mean percentage of innovation, measured in patents granted is equal to 6.604 with a very wide range. The lowest number of patents granted is 17 while the highest number is 108,622. The observation of 17 was for Iceland in 1981, while the largest observation was for the United States in 2011. The mean rate of entrepreneurship is equal to 9.91% with a range between 5.59% and 16.49%. I look into this number in more detail below. For intellectual property, the index ranges between zero and five, with five representing very high and strict property protection. This means that I can conclude from the mean that in general the level of intellectual property protection in our sample of countries is very high.

[47] For data sources, please see the previous chapter.

Second, the table below describes the correlations between the different variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Output (Y)	1											
2. Labor	0.98	1										
3. Capital	0.93	0.94	1									
4. Output/labor $\left(\frac{Y}{L}\right)$	0.39	0.31	0.31	1								
5. Capital/labor $\left(\frac{K}{L}\right)$	0.19	0.20	0.42	0.52	1							
6. Innovation (I)	0.97	0.94	0.93	0.36	0.26	1						
7. Innovation/labor $\left(\frac{I}{L}\right)$	0.44	0.43	0.49	0.22	0.44	0.51	1					
8. Entrepreneurship (E)	0.05	0.07	0.01	-0.00	-0.36	0.02	-0.09	1				
9. Education	0.25	0.19	0.18	0.59	0.19	0.26	0.30	0.19	1			
10. Research & Development	0.99	0.97	0.95	0.38	0.25	0.98	0.48	0.01	0.25	1		
11. University-Industry relations	0.02	-0.01	-0.05	0.16	-0.11	-0.01	0.09	0.27	0.18	0.01	1	
12. IP protection	0.38	0.37	0.38	0.62	0.36	0.35	0.14	0.02	0.51	0.38	0.07	1

TABLE 6: CORRELATIONS (N=527 FROM 17 COUNTRIES OVER 31 YEARS)[48]

The table shows the correlations between the different variables. What becomes immediately clear, are the very high correlations between GDP and labor, capital, innovation and research and development. All these correlations are above 0.9. These high correlations are also present between innovation and labor (0.94), capital and labor (0.94), labor and R&D (0.97), capital and innovation (0.93), between capital and R&D (0.95), between R&D and innovation (0.98). The high correlations stem from differences in country size. Countries with a larger size will automatically have a higher level of capital and a larger labor force. By using fixed effects estimations, I focus on the variations over time instead of country differences.

Third, the table below describes the development in the business ownership rate over the time period. 2006 is added as the last year before the economic crisis. The table shows the level of the business ownership rate at four different points in time. It shows that there are large differences between the countries while the differences over time are not that large. For example, in 2011, Australia had a business ownership rate of 14.3% while in Denmark it was only 6.9%. These differences were even larger in 1981 (6.5% versus 16.1%). Freytag & Thurik (2007) find that these differences are related to differences in institutions and cultural approaches between the countries.

When focusing on the differences within the 31 years, it is visible that most countries have seen an increase in entrepreneurship during the last few years. Some countries, like France, have seen a decrease between 1981 and 2001 but have increased afterwards. Most countries have remained stable or seen an increase between the start of the economic crisis and 2011. A possible explanation might be that during the economic crisis more people became unemployed. These people might start a new business in order to provide in their personal income. This is known in the literature as the unemployment push-effect or '*refugee effect*' (Thurik, Carree, Van Stel, & Audretsch, 2008). An exception is for example Iceland, which has seen a two percentage point decrease in that period. From the 17 countries, over the whole time period, 11 have seen an increase in the business ownership rate, while one country (Denmark) has remained equal. Japan has seen the largest decrease which is 5.3 percentage points.

[48] For data sources, please see the previous chapter.

	Business Ownership Rate, 1981-1991-2001-2006-2011				
Country	1981	1991	2001	2006	2011
Australia	16.1%	15.8%	15.3%	15.1%	14.3%
Austria	7.0%	7.1%	8.5%	9.1%	9.2%
Belgium	9.8%	11.3%	11.5%	11.3%	11.4%
Canada	8.6%	10.8%	12.5%	11.8%	11.8%
Denmark	6.9%	6.0%	6.4%	6.9%	6.9%
Finland	6.4%	7.8%	7.8%	8.6%	9.4%
France	10.1%	9.6%	7.9%	8.3%	9.2%
Germany	6.5%	7.1%	8.6%	9.7%	10.3%
Iceland	7.4%	10.4%	10.8%	11.3%	9.3%
Japan	13.0%	11.3%	9.2%	8.7%	7.7%
Netherlands	8.0%	8.2%	10.3%	11.3%	12.0%
New Zealand	9.4%	11.7%	13.5%	13.0%	11.9%
Norway	8.3%	7.8%	6.4%	8.8%	7.8%
Spain	10.9%	12.6%	12.9%	13.3%	11.1%
Sweden	7.0%	6.8%	8.2%	8.5%	8.7%
United Kingdom	8.1%	10.8%	10.4%	11.2%	11.7%
United States	9.8%	10.8%	10.0%	10.1%	9.0%

TABLE 7: BUSINESS OWNERSHIP RATE (SOURCE: COMPENDIA 2011.1 DATABASE)

6.3 Results

After describing the descriptive statistics, the results will now be discussed. First, the economic growth equation will be discussed, second the innovation equation. To catch-up, these are the two equations which will be estimated:

$$\ln\left(\frac{Y}{L}\right)_{it} = \alpha_i + \beta_1 \ln(I)_{it} + \beta_2 \ln\left(\frac{K}{L}\right)_{it} + \beta_3 \ln(L)_{it} + \beta_4 E_{it} + \beta_5 Education_{it} + \varepsilon_{it} \tag{39}$$

$$\ln\left(\frac{I}{L}\right)_{it} = \delta_i + \gamma_1 \ln(R\&D)_{it} + \gamma_2 E_{it} + \gamma_3 Education_{it} + \gamma_4 \ln\left(\frac{Y}{L}\right)_{it} + \gamma_5 \ln(L)_{it} + \gamma_6 University\ industry\ relations_{it} + \gamma_7 \ln(IP\ protection)_{it} + \mu_{it} \tag{40}$$

All equations will be estimated using a combination of two-stage least squares and fixed effects techniques. The results of the first stages are not reported. The decision to work with fixed effects is taken based on the outcomes of the Hausman test. The Hausman test can help pick the correct method of estimation for panel data regressions. Using the test, the decision is made to use fixed effects instead of pooled OLS or random effects estimation. The null hypothesis under the Hausman test is that the x_{it} and α_i (or as denoted in the second equation x_{it} and δ_i) are uncorrelated. The test compares two estimators, one which is consistent under the null hypothesis and one which is both consistent under the null hypothesis and the alternative hypothesis. If the difference between both estimators is significant, the null hypothesis is very unlikely to hold (Hausman, 1978). At all occasions the outcome was significant at the 1% level.

Additional models

Because the specific focus of this thesis is on entrepreneurship, two other variations were researched within this framework.

First, I researched if there was a possible optimal level for entrepreneurship. In order to do so, one should include a second-order polynomial of entrepreneurship ($entrepreneurship^2$) into the equation. The optimal level can be calculated as follows. To show, I use a simplified example:

$$\ln\left(\frac{Y}{L}\right) = \alpha + \beta_1 E + \beta_2 E^2 + \varepsilon \tag{41}$$

$$E^* = -\frac{\beta_1}{2\beta_2} \tag{42}$$

Thus, using the parameter for both singular entrepreneurship and entrepreneurship-squared, the optimal level can be determined. From the signs of the two betas, one can deduct if the relationship is U-shaped or has an inverted U-shape. This also allows to derive if there are decreasing marginal returns to entrepreneurship. Decreasing marginal return would indicate that after a certain level of entrepreneurship, the effect on the independent variable becomes negative. The theoretical foundation for this inclusion is the idea that there might be an optimal level of entrepreneurship to provide economic growth or innovation. One argument for this is based on intuition. Evidence suggests that in poorer countries, or less economically developed countries, rates of entrepreneurship are higher compared to more developed countries (Blanchflower, 2004). This finding does not support the idea that more entrepreneurship is always better but that there might be a certain optimum. Another reason, more related to my theoretical framework is that not all entrepreneurs contribute to growth to a great extent. There is an obvious difference between them, and one could argue that only the entrepreneurs with the largest amount of entrepreneurial ability are able to help the economy further. Only this top of the iceberg is productive, *i.e.* more productive than they would be as an employee (*e.g.* Hartog, Van Praag & Van der

Sluis, 2010). Other entrepreneurs with less of this endowment may be more productive in an employee environment for example. As a consequence, not all entrepreneurs are the same, meaning that not an ever increasing number of entrepreneurs is the obvious best choice for economic growth. Empirically, Van Praag & Van Stel (2013) found such a rate when explaining economic growth. They use a sample of 19 OECD countries over the period between 1981-2006 and find robust results for the existence of an optimal business ownership rate.

Second, using the KTSE-theory as a starting point, I also wanted to focus on the relationship between entrepreneurship and R&D – both innovation inputs – in the form of an interaction term. In this theory entrepreneurs need knowledge from another source for their new firm: they usually do not create knowledge themselves. This knowledge does provide the economic opportunities necessary for the entrepreneur. The entrepreneur is the one who recognizes the opportunities while the firm where the knowledge was created does not. By materializing these opportunities in his new firm, the entrepreneur breaks through the knowledge filter. It is important to state here that the knowledge creator and entrepreneur can be the same person, but that the firm in which the knowledge is commercialized differs. The person of the entrepreneur can be the scientist who created the knowledge (as an employee in an incumbent firm) but he cannot commercialize it with his own employer. Therefore he decides to start his own firm. Thus, the effect of entrepreneurship might also depend on the amount of R&D available. More R&D should yield more opportunities and possibly more economic growth. In order to research this theory, interaction terms can also be included in the regression models.

In the economic growth model I use the cross-term between innovation and entrepreneurship. Here both are viewed as the input factors for economic growth. The same logic applies as above.

6.3.1 Economic growth

In the following table, the results of the economic growth equation are provided. The expectation of the first hypothesis was that entrepreneurship has a positive, direct effect on economic growth. This is also the expectation for the other variables in the equation. Entrepreneurship can increase diversity and competition in the economy leading to more growth. Innovation, for example, can increase the knowledge stock, which in turn provides higher growth rates.

The first model, denoted as (1) in the table, describes the basic model. This model does include all variables described above. Model (1) represents the base model. Model (2) adds the quadratic term of entrepreneurship while the third model adds the interaction term between entrepreneurship and innovation. Lastly, model (4) includes both additional variables in the equation. The coefficients are provided below, as well as the standard errors. The stars represent significance of the variables. Lastly, the R^2 is shown to provide information on the fitting of the model. Because I work with panel data, specifically fixed effects, this is the within R^2. The within R^2 is based on the within transformation, which was discussed in the previous paragraph. It can be interpreted as the amount of time variation in the dependent variable that can be explained by the time variation within the independent variables (Wooldridge, 2002b). Rho explains the amount of variation which is due to differences across panels. The F-test explains whether the coefficients of the explanatory variables in the model are all significantly different from zero.

Dependent variable: Ln(GDP/Labor)				
	(1)	(2)	(3)	(4)
Constant	5.396***	5.359***	4.942***	4.896***
	(0.414)	(0.412)	(0.377)	(0.376)
Ln(Capital/labor)	0.467***	0.468***	0.466***	0.469***
	(0.029)	(0.029)	(0.032)	(0.032)
Ln(Labor)	-0.094***	-0.093***	-0.049	-0.049
	(0.031)	(0.031)	(0.032)	(0.032)
	$\hat{\beta}$ =0.439	$\hat{\beta}$ =0.439	$\hat{\beta}$ =0.485	$\hat{\beta}$ =0.482
Ln(Innovation)	0.097***	0.096***	0.106***	0.102***
	(0.014)	(0.014)	(0.022)	(0.021)
Education	0.217***	0.217***	0.224***	0.225***
	(0.023)	(0.031)	(0.023)	(0.023)
Entrepreneurship	1.067***	1.520	2.721***	3.306*
	(0.225)	(1.247)	(1.047)	(1.739)
Entrepreneurship²		-2.232		-3.496
		(6.059)		(6.146)
Entrepreneurship*Ln(Innovation)			-0.243	-0.225
			(0.153)	(0.150)
Number of observations	527	527	527	527
Optimal Entrepreneurship rate				
Within R^2	0.8938	0.8942	0.8937	0.8943
Rho	0.936	0.935	0.926	0.926
F-value	170.32	169.72	170.51	170.58

TABLE 8: REGRESSION RESULTS EXPLAINING LN(GDP/LABOR), 17 COUNTRIES BETWEEN 1981-2011 USING FIXED EFFECTS ESTIMATION.

A) ESTIMATION METHOD IS TWO-STAGE LEAST SQUARES, FIXED EFFECTS
B) SIGNIFICANTLY DIFFERENT FROM ZERO AT P<0.01 IS DENOTED BY ***, P<0.05 IS DENOTED BY **, P<0.1 IS DENOTED BY *
C) STANDARD ERRORS ARE PRESENTED IN PARENTHESES
D) INNOVATION IS ENDOGENOUS
E) ENTREPRENEURSHIP, EDUCATION, LABOR, CAPITAL-LABOR RATIO, R&D, UNIVERSITY-INDUSTRY RELATIONS AND IP PROTECTION ARE USED AS INSTRUMENTS

Before describing the results, it is important to note that before interpreting the effect from the labor variable, a calculation should take place. In the prior chapter, I showed that when dividing the equation by labor and using logarithms, the following equation emerges.

$$\ln\left(\frac{Y}{L}\right) = \ln A + \alpha \ln\left(\frac{K}{L}\right) + (\alpha + \beta - 1)\ln(L) + \gamma \ln I + \delta_1 E + \delta_2 Education \qquad (43)$$

Using the coefficients from labor and the capital-labor ratio from table 8, I calculated the labor coefficient. This coefficient is always positive, around 0.439. It is significant in both the first and second model.

The model is specified in logarithms or percentages on both sides of the equation. This implies that all coefficients can be interpreted as (semi-)elasticities. In abstract terms, the interpretation of an elasticity is as follows, an increase in factor j by 1% implies that the dependent variable will increase with β_j%. For semi-elasticities, an increase in factor j by 1 percentage point implies that the dependent variable will increase with β_j%. As an example, this implies that if entrepreneurship increases with one percentage point, GDP/labor will increase with 1.067%, holding constant all actual levels of the other production factors. To illustrate the magnitude of this result, suppose that the mean of the business ownership rate is 10%.[49] If the business ownership rate increases with one percentage point, the business ownership rate goes from 10% to 11%, which is an increase of 10% in reality.

[49] In reality in this dataset, the mean of the business ownership rate (entrepreneurship) is 9.9%, see table 5.

The results from the first equation indicate that both capital and labor are important determinants of economic growth, as denoted by significant and highly positive coefficients. This was also the idea in the Solow (1956) growth model where the capital/labor ratio was one of the factors influencing economic growth. This idea continued to exist in the more recent growth models. These findings are thus consistent with the theory. Additionally, education is found to have a positive influence as well. This implies that human capital, and its quality also has an influence on economic growth. This in line with what the model of endogenous growth suggest, namely that human capital is an important factor and plays a role. It can represent technology in the growth factor as well (*e.g.* Lucas, 1988). The influence of education remains significant and around 0.22.

Based on the endogenous growth models, the innovation variable is also an important driver of economic growth. The influence of innovation is very important in the growth models. In remembrance, the main idea is that firms invest in R&D in order to get a competitive advantage over their competitors, but not all knowledge remains at the firm. These knowledge spillovers add to the societal knowledge stock. This availability of knowledge in the nation silently also augments the production function of other firms or generates opportunities for entrepreneurs. This explains growth disentangled from labor supply or physical capital investments and thus, even when capital and labor remain constant, these increases in knowledge can cause growth to continue to exist. The conclusion on the positive effect of innovation is underlined here by the highly significant and positive results of this variable. The variable indicates that a 1% increase in the number of patents, or in innovation, leads to a positive impact of around 0.1% on the GDP/labor ratio. The positive effects of labor, capital and innovation provide support for Romer's view that knowledge matters as a production factor. However, I find support that knowledge output matters, while Romer focused on knowledge input. The effect of innovation remains stable and significant over all models. The sizes of the coefficients of labor, capital and innovation have to do with their shares in the production factor. In theory, the coefficients together form the production process. The plausibility of this assumption is illustrated by $\alpha + \beta + \gamma = 1$, the constant returns to scale assumption. The summation for all regression models is around 1 in this sample. From this it follows that innovation has a weight of around 10% - in this sample – of all production factor inputs. Capital and labor both have a similar weight of around 45%. Entrepreneurship and education are factors illustrating the economic context. For example, the same amount of input factors leads to more output if this input is divided over more production units (firms) or if they are handled by a higher educated labor force. The factors which explain innovation will be discussed in the next subsection.

Now, most interesting are the results of the factor entrepreneurship. First, the focus should be on the first model where entrepreneurship plays a highly significant and positive role. For each 1 percentage point increase in entrepreneurship, an increase in GDP per laborer of 1.067% occurs. Increasing entrepreneurship implies setting up more new firms which can help with the commercialization of generated knowledge. This provides evidence that entrepreneurship is indeed an important production factor, as introduced in the Knowledge Spillover Theory of Entrepreneurship. This finding can hence provide evidence and support for the idea that the focus of public policy should shift to or include entrepreneurship. The potential potent influence of entrepreneurship deserves and requires more attention in the future.

Models (2), (3) and (4) represent different robustness checks as introduced above. They provide no evidence for an optimal relationship between entrepreneurship and economic growth. This based on the insignificance of the quadratic term in the equation. In contrast to Van Praag & Van Stel (2013) who do find this relationship, adding a quadratic term does not improve the fit of the model. From the results, I can therefore not infer that there is an optimal level of entrepreneurship and if the relationship between entrepreneurship and economic growth is U-shaped.[50] Second, an interaction effect between entrepreneurship and innovation is not found. This means that the effect of entrepreneurship does not depend on the level of innovation and vice versa. This is contradictory to the KTSE-theory where the assumption is that more knowledge leads to more economic opportunities for entrepreneurs. However, one could argue that the economic opportunities from the model are

[50] The most likely explanation is that Van Praag & Van Stel (2013) included additional countries, in particular Greece and Italy, which have exceptionally high business ownership rates.

based on economic inputs. R&D activities from other firms which do not commercialize are the main source. In other words, the opportunities related to the patents have already been taken by entrepreneurs. In this paper, innovation is measured as granted patents. This means that I use a measure for outputs, for opportunities which have been protected by others and have been utilized by others. This is not to say that these patents might provide inspiration for others, for imitation entrepreneurs. The measure for entrepreneurship in this paper is however too broad to only cover imitative entrepreneurs. This might be an interesting direction for further empirical research.[51]

The evidence presented above is in line with earlier studies which have also shown the importance of labor, capital and education. New here is that it is now shown, for a panel of 17 countries, that entrepreneurship is an important production factor for economic growth. This conclusion also goes for innovation, measured as output factor. The pay-off of entrepreneurship may even be larger if it is can be proven that entrepreneurship also positively influences innovation. This is a question that I will now further analyze.

6.3.2 Innovation

The following table on the innovation equation is set-up in the same way as the economic growth equation in the previous table. This table helps to answer first part of the second hypothesis where the expectation was that entrepreneurship should have a positive effect on innovation, which in turn influences economic growth positively. This is the indirect effect of entrepreneurship on economic growth. All models use $\left(\frac{I}{L}\right)$ as dependent variable. Due to this method of estimation, the real coefficient for labor has to be calculated. This goes as follows (using a simplified Cobb-Douglas function to illustrate):

$$I = AR^{\alpha}L^{\gamma} \tag{44}$$

$$\frac{I}{L} = AR^{\alpha}L^{\gamma-1} \tag{45}$$

$$\ln\left(\frac{I}{L}\right) = \ln A + \alpha \ln(R) + (\gamma - 1)\ln L \tag{46}$$

From this exercise, it follows that the 'real' coefficient for labor (γ) can be estimated by adding 1 to the estimated coefficient.

The first model, denoted as (1) in the table, describes the basic model. This model does include all variables described above. Model (1) represents the base model. Model (2) adds the quadratic term of entrepreneurship while the third model adds the interaction term between entrepreneurship and R&D. Lastly, model (4) includes both additional variables in the table. The coefficients are provided below, as well as the standard errors. The stars represent the significance of the variables.

[51] For a theoretical model where different types of entrepreneurship and economic growth are related, please see Minniti & Lévesque (2010).

Dependent variable: Ln(Innovation/Labor)				
	(1)	(2)	(3)	(4)
Constant	-9.410***	-9.082***	-10.481***	-10.084***
	(2.144)	(2.136)	(2.182)	(2.177)
Ln(Research & Development)	0.715***	0.756***	0.770***	0.804***
	(0.056)	(0.057)	(0.059)	(0.060)
University-Industry Relations	-0.241	0.003	-0.094	0.122
	(0.352)	(0.359)	(0.354)	(0.360)
Ln(IP protection)	0.352***	0.222	0.388***	0.263*
	(0.133)	(0.139)	(0.133)	(0.139)
Ln(GDP/Labor)	0.554***	0.604***	0.485**	0.538***
	(0.204)	(0.203)	(0.203)	(0.202)
Ln(Labor)	-.0.587***	-0.632***	-0.443	-0.496***
	(0.110)	(0.110)	(0.123)	(0.123)
	$\hat{\beta}$ =0.412	$\hat{\beta}$ =0.368	$\hat{\beta}$ =0.557	$\hat{\beta}$ =0.504
Education	0.001	-0.009	0.033	0.022
	(0.106)	(0.106)	(0.106)	(0.106)
Entrepreneurship	-4.079***	-18.444***	4.979	-9.241
	(0.869)	(4.940)	(3.596)	(6.238)
Entrepreneurship^2		71.266***		66.810***
		(24.110)		(24.034)
Entrepreneurship*Ln(R&D)			-1.034***	-0.948**
			(0.398)	(0.396)
Number of observations	527	527	527	527
Optimal Entrepreneurship rate		0.129		NA[52]
Within R^2	0.8131	0.8159	0.8160	0.8185
Rho	0.953	0.954	0.961	0.961
F-value	224.79	222.24	227.10	223.59

TABLE 9: REGRESSION RESULTS EXPLAINING LN(INNOVATION/LABOR), 17 COUNTRIES BETWEEN 1981-2011 USING FIXED EFFECTS ESTIMATION.

A) **ESTIMATION METHOD IS TWO-STAGE LEAST SQUARES, FIXED EFFECTS**
B) **SIGNIFICANTLY DIFFERENT FROM ZERO AT P<0.01 IS DENOTED BY ***, P<0.05 IS DENOTED BY **, P<0.1 IS DENOTED BY ***
C) **STANDARD ERRORS ARE PRESENTED IN PARENTHESES**
D) **GDP/LABOR IS ENDOGENOUS**
E) **R&D, UNIVERSITY-INDUSTRY RELATIONS, IP PROTECTION, EDUCATION, ENTREPRENEURSHIP, LABOR, AND THE CAPITAL-LABOR RATIO ARE USED AS INSTRUMENTS**

The results show that multiple factors are of influence on innovation. Innovation is expressed in this equation as number of patents per laborer in order to specify it as a relative term. This is to correct for the size of the country and the number of laborers available to introduce the inventions. All models have a high within R^2 and the same number of observations.

The first interesting result from this table follows from the coefficients of the R&D variable. In the theory section, it was discussed at length that a well-developed knowledge stock forms a crucial determinant for economic performance of a country in general. New knowledge needs to be generated to keep this knowledge stock full and up-to-date. In all models the effect of a 1% increase in R&D expenditures in a country denote to a less than 1% increase in innovation, namely around 0.75%. This finding provides evidence for the suggested knowledge filter. The knowledge filter represents the gap between newly created knowledge and commercialized knowledge. Translating this to the model, the former is represented by the R&D investments and the latter is represented by innovation. With the knowledge filter, I suggested a four step process through which knowledge has to go before it turns into a real innovation. This includes steps as the open society, institutional, economic value and commercial value filter. The filter represents the idea that not all knowledge which is generated will

[52] The optimal level also depends on the level of $\ln(R\&D)$.

be applied in a real product or service. Some investments will be left behind, but will form an addition to the knowledge stock. From the coefficients one can gather that around 25% of the investments stay behind in the filter. The different filters can explain why, for example, the invention is not working or scalable. Firms can also decide that it is not attractive enough on a commercial front. Of course, there is also always a certain amount of waste or efficiency loss in the process which can explain part of the residue.

Interesting is to see if the knowledge filter exists to the same extent for private and public R&D activities. In order to research this option, I ran the same models, once with public expenditures on R&D and once with private expenditures on R&D. Both variables arrive from the OECD *Science, Technology and R&D* database for the years 1981-2011. Private expenditures are defined as *"Expenditures on R&D in the Business Enterprise Sector".* I use constant in millions, 2005 US dollars and 2005 PPP. Public expenditures are the sum of the *"Expenditure on R&D in the Business Enterprise Sector"* and *"Expenditure on R&D in the Higher Education Sector".* This variable as well is denoted in millions, constant 2005 US dollars and 2005 PPP. I hereby assume that R&D expenditure in higher education is largely funded by governments in the countries in my sample. In order to answer this question, both R&D private and R&D public should be included in the estimation together.[53] The results indicate that private R&D expenditures are more effective compared to public sector R&D expenditures. Both types of R&D have a positive and highly significant effect on innovation output. The coefficient for private expenditures is higher compared to the coefficient for public expenditures. This provides evidence for the idea that private companies are more efficient in their R&D activities compared to private companies. They are more likely to create knowledge without a delay and commercialize it in new products. This is because most research projects in firms are already shaped towards possible applications.

Another topic which was discussed in the theory section relating to the knowledge filter is intellectual property rights. The variable IP protection controls for that in my regression. In every model the influence is positive. For example in the first model, a 1% increase in IP protection leads to a 0.352% increase in innovation per laborer. This suggests that in the sample as a whole, a stricter protection of intellectual property rights does have a positive influence on innovation. The incentive to innovate can therefore still be increased by protecting inventors better. Relating this to the theory section, there it was proposed that an inverse U-shaped relation may exist between intellectual property rights and the number of innovations in the economy. In short: at first stronger rights are positive because they increase the incentives to innovate. People are more able to attribute the rents from their invention and make a profit. However, after the top, the stronger intellectual property right protections do not increase the number of innovations because they effectively block the access to the knowledge stock. This means that others who want to innovate do not have the access to the knowledge required to actually make this wish come true. To test this assumption in my sample, I ran the regression of model (1) from table 9 again with the additional variable $\ln(IP\ protection)^2$. The inclusion of the square term of intellectual property rights allows me to test whether there is a quadratic relation between innovation output per laborer and the level of IP protection.[54] The results however show that in the sample no evidence is present of a quadratic relationship. This does not indicate however that for individual countries an optimum is not available. One should keep in mind that these results are general results over the whole sample and do not provide evidence that every country is at the same place of the curve or does not have an individual optimum. For example, the results do thus not falsify the statement of Jaffe & Lerner (2004) that the United States patent system has become too strong. Another test related to this theory is the inclusion of an interaction term between entrepreneurship and IP protection. This interaction term should have a negative sign: stricter intellectual property rights protection is expected to have a negative effect on the level of entrepreneurship. It namely indicates less knowledge spillovers thus also fewer opportunities for entrepreneurs. Empirically, I do not find evidence for this proposition.[55]

[53] See table 16 in the appendix for the results of these regression models.
[54] See table 17, model (2) in the appendix for the results of this regression model.
[55] See table 17, model (3) in the appendix for the results of this regression model.

The model does not provide evidence for the theoretical positive effects of education and university-industry relations. Both variables have alternating signs and are not significant in any of the models. For university-industry relations, this means that I cannot confirm the finding that the relationships between universities and industry are an additional conduit to survive the knowledge filter. A possible explanation is in the chosen proxy for these relations. I used the percentage of funding that universities received for private partners to model this relationship. It is well possible that this proxy only has effects in certain sectors of the economy or when the university and company are in proximity to each other. It might be that the macro-level chosen here, focusing on many different countries, is too high to show this connection. Also, it is interesting to know what the money is used for: how specific is it? Are there certain projects which are funded with a specific research question? Is there more than just a fund? Further research can try to answer these questions and focus on finding a better proxy to research this effect. This research can also focus on the regional level or individual country level to see if the relationship holds there.

For education, I also do not find the expected effect. This is interesting because education did have a direct effect on economic growth as was shown in the previous model (see table 8). A possible explanation is the sample for which this factor is included. All countries are highly developed and have seen rising levels of education in recent years. A lot of countries have reached the 90% mark or higher in recent years. It might be that the level of development in all countries is already so high that additional units of education have a very small or non-existent effect on the level of innovation. This should not be confused with no (positive) effect on economic growth. If the level of education rises, the skills level of the labor force increases as well. The higher skilled the labor force is, the better human capital is available. This in turn can increase the level of economic growth. Another reason might be the high correlation between education and GDP per laborer which leads to the disappearance of any effect of education. The variable GDP/labor is always positive and highly significant.[56] For every 1% increase in GDP/labor, the innovation/labor variable increases with around 0.5%. This suggests that more developed countries are even better in innovation. Some knowledge production function equations include a variable measuring physical capital. For estimation purposes (identification of the equations) it is also necessary to have at least one variable that is present in the first equation but not present in the second equation. This is the capital variable in my case. I therefore argue that using GDP/labor in the second equation is enough, based on the idea that countries with a higher GDP/labor also have more physical capital.

Labor plays a positive role in the equation. The effect is significant in most models. The results for labor represent that a higher number of laborers increases the number of innovations. In general, more people working in the economy yields positive results with a coefficient of around 0.45. This means that the input share of labor for the innovation production function is quite large. The factor labor is defined very broad; it contains the total labor force which is employed at the moment. The number of people in this force which are actually involved in innovation will be very slim. The negative effect on the share of innovation represents this: only a few of the additional workers will yield innovations and patents. It might very well be that the entrepreneurs are the ones who yield the innovations. This is in line with the idea of Schumpeter (1934) who thought that entrepreneurs are the ones who bring the innovations by commercializing inventions. The entrepreneurs are represented both in the labor sample (labor also represents the business owners) and as a control variable.[57] Entrepreneurship is included in the absolute labor force to represent the work which is done by the entrepreneurs. In this sense, entrepreneurs are similar to the input provided by employees. The second variable entrepreneurship, the business ownership rate, indicates the context of the economy. It represents the level of competition under which economic output has been produced.

[56] Running the regression again without the GDP/labor variable means that a simple fixed effect estimation is applied (no 2SLS because no endogenous variable is present). The results of this regression are a positive (around 0.2) and highly significant (1% level) effect for education in all four models. The results are presented in the appendix (see table 18). Please note that the results for the other variables remain more or less the same.

[57] The labor force represents the absolute sample, the entrepreneurship variable is a relative measure.

Now, the discussed variables cannot be the only driver of economic growth. However, most literature which tries to explain economic growth or innovation does draw on R&D as the only driver for economic growth. R&D is the main driver because of its ability to produce technological change. This idea cannot hold in the empirical world. They are not able to explain the exceptional growth in recent years by countries as China or the lack of growth in countries as Japan. China has virtually no existing R&D expenditures while Japan does have significant expenditures. So another factor should be identified. One of the potential factors having this impact is entrepreneurship as I argued in the theory section. Baumol (2002) is one of the scholars who explicitly separates the entrepreneur, who has a risk-taking function within the innovation process, from other, existing incumbent corporations. These larger firms are involved in the routine process of large scale innovation, while the smaller firms, the entrepreneurs are often involved in other breakthroughs and new products. Although, the large firms do have a quantitatively more important influence as more R&D expenditures but also more patents are provided by them, a number of studies have found that the real breakthroughs are often introduced by the entrepreneurs (*e.g.* Acs & Audretsch, 1988).

Switching to the empirical results, it is interesting to see that entrepreneurship yields a highly significant but also negative result on innovations in the first regression model (1). This is completely contradicting the theory which assumes that entrepreneurs play a large role in using economic opportunities in the form of available knowledge and turn them – by creating a new firm – into innovations. To research this surprising result further, I added a quadratic term to the equation, as can be viewed in model (2). This coefficient is both highly significant and positive. The combination of the negative coefficient for entrepreneurship and the positive coefficient for entrepreneurship squared leads to the conclusion that a U-shaped relation exists between innovation and entrepreneurship. To illustrate this, I use the following figure:

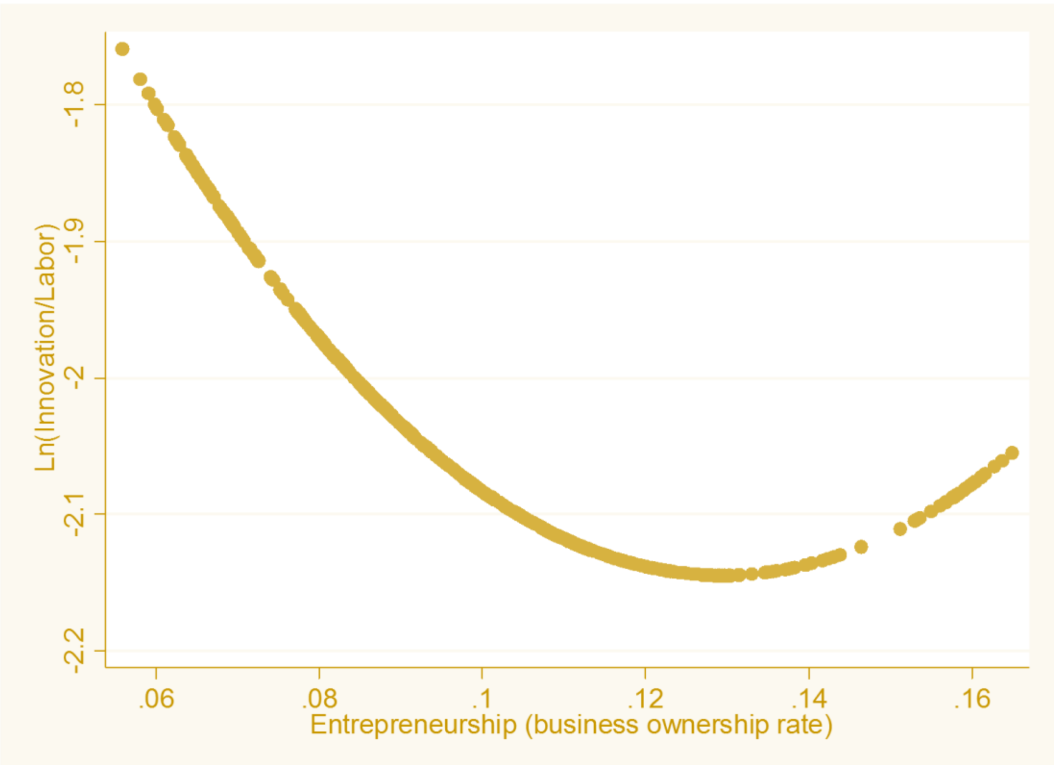

FIGURE 7: RELATIONSHIP BETWEEN ENTREPRENEURSHIP (BUSINESS OWNERSHIP RATE) AND LN(INNOVATION/LABOR). NOTE: THE FIGURE IS BASED ON THE ESTIMATES OF EQUATION 2 IN TABLE 9.

The table illustrates the relationship between innovation per laborer (expressed in logarithms) and entrepreneurship – expressed as the business ownership rate. The turning point of the graph lies at 0.129 or at a business ownership rate of 12.9%. Before this turning point, more entrepreneurship negatively affects innovation while after the turning point this effect becomes positive. This number is quite high, from all observations in the sample (527: 17 countries over 31 years), only 58 observations are above this threshold. The figure illustrates this, it can be viewed that most observations are below the threshold. Below I try to explain the U-shaped relationship between entrepreneurship and innovation as visible here.

In order to explain the U-shape, I use several theories which have been applied in the past to research on economic growth in cities (*e.g.* Glaeser *et al*., 1992) or regions (*e.g.* Van Stel & Nieuwenhuijsen, 2004). The models used in these papers also start from the belief that knowledge spillovers are of major importance for innovation as well as economic growth. Knowledge spillovers are used to explain the difference in growth rates between cities or regions based on the line of reasoning that one district can more efficiently use the knowledge spillovers than the other. These are knowledge spillovers in the classical sense. The model used in these papers incorporates three theories which focus on the impact of knowledge spillovers and competition. I have touched lightly on three elements that are relevant here: competition, diversity and specialization when discussing the second hypothesis of this paper.[58] Now I will discuss this further.

The first theory is presented by Marshall (1890), Arrow (1962a) and Romer (1986) and is usually referred to as the MAR-theory. First, the assumption of these three scholars is that for spillovers to be most effective they have to occur between two homogeneous entities. *Intra-sector spillovers* are thus assumed to be more efficient than *inter-sector spillovers*. This indicates that specialization is positive for spillovers because of the limited number of activities left. These activities are similar which indicates that spillovers can occur more easily and provide economic growth. Glaeser *et al.* (1992, p. 1130) provide the example of Silicon Valley where most spillovers occurred based on the microchip industry. Interesting for this topic is that Marshall, Arrow and Romer are advocates for local monopolies. They think that these monopolies are beneficial for economic growth because it allows the inventor to attribute the rents of his innovation. The inventions are easier to protect from others. In economic terms, the vast yields are required by the inventor because he internalizes the externalities which are associated with their innovation. In short, local monopoly creates an additional incentive to innovate. Their position on competition is thus equal to Schumpeter (1934) who also predicts that local monopoly is preferred over competition.

The second theory is created by Michael Porter in 1990. The MAR economists and Porter both agree that spillovers have a higher impact in specialized sectors but they do disagree on the role of competition. While the MAR economists believed in a local monopoly, hence no competition, Porter believes that competition can have a positive role. He believes that competition will increase innovation as well as imitation which will both increase economic growth. Porter does acknowledge that the rents for the individual innovator will decrease because he will not be able anymore to receive all yield of the innovation due to larger spillovers. However, he states that the pressure to innovate which comes from more competition more than offsets this. Firms will be 'forced' to innovate because they do not want to be left behind. Firms that do not innovate will lose ground on their competitors which in the end leads to bankruptcy. He provides the example of the Italian ceramics and gold jewelry industry. Here competition is fierce while the firms are in close proximity to each other. These firms closely compete and try to innovate to survive. Thus, specialization and competition are both positive sources which will lead to economic growth.

The last theory originates from Jacobs (1969). Her approach is different from Romer and the MAR economists because her vision is that instead of specialization, spillovers work best when different companies are involved. She favors *inter-sector spillovers*. Diversity is thus important and regions or countries with high levels of diversity will show high economic growth rates. As for competition, Jacobs agrees with Romer and assumes that local

[58] See subsection 4.4 "Research question and hypotheses".

competition has a positive effect. It increases the rate at which new technologies are adapted and thus leads to stimulating economic growth.

The three theories, although they have overlaps, are competing theories. They differ in their believes on the type of spillover that is efficient and the role of competition. Three key words are thus specialization, diversity and competition. These three theories can be related to the figure as shown below. I argue that the left-hand of the minimum level can be explained based on the theory of Marshall, Arrow and Romer while the right-hand side can be explained by Porter and Jacobs. I focus on the explanation that the theories provide for the role of competition. These theories are usually applied in studies which focus on explaining economic growth directly; however the theories all use knowledge spillovers and innovation to explain economic growth. In order to apply the theories, I interpret the business ownership rate here as a measure of competition. A higher business ownership rate indicates a higher number of business owners and thus a higher number of firms in the economy. The assumption is that more firms also equals more competition. Focusing on the role of competition for innovation, these theories explain the positive and negative effect of entrepreneurship visible in the graph.

From the graph, we see that I associate the Marshall, Arrow and Romer theory with lower values of the business ownership rate while I associate Porter & Jacobs with the higher values. The slope of the left-hand side of the graph is steeper than the right-hand side. This can be explained by the concept of increasing marginal returns. In order to explain, I have to make the assumption that innovations and inventions will always lead to spillovers for the society. These spillovers increase the competition very much when you lose your monopoly and a second firm starts producing the product. When there is a lower number of companies, spillovers will have a larger impact because your competition will double or triple at once. The spillovers for an additional company when the starting number of companies is already high, for example the 1001st or 1002nd company will not have such a large impact. Protection of your own property and having lower numbers of competition is thus very important when the number of competitors is relatively low.[59] This idea is supported by the theory of the MAR economists who find a local monopoly favorable for innovations and economic growth. Because of these spillovers, the intention to innovate of the individual firm will decrease at a fast pace, which will weaken in proportion as the number of business owners increases. This is shown in the graph by the lessening negative effect of entrepreneurship as denoted by the slope of the graph.

This concept and theory holds upon the turning point which lies at a business ownership rate of 12.9%. After this point the competition is so fierce, the number of companies is so high, that firms simply have no choice: they have to innovate. Every company which is then a part of the economy is forced to innovate in order to be able to survive. Enterprises do not limit their innovative actions anymore out of fear that others will profit from the spillovers: this is not an influential consideration anymore. Firms innovate at a higher rate to avoid a backlog compared to their counterparts in this situation.

Together with the positive results found from entrepreneurship for its direct effect on economic growth, these findings indicate that entrepreneurship does play an important role in the economic world. It cannot only help innovation but also economic growth. The research presented here does however indicate that in order to make the positive effect of economic growth as large as possible, it is required to have a high level of entrepreneurs in the economy as a whole.

[59] See also the discussion on intellectual property rights above. This argument could be tested with the interaction term between entrepreneurship and intellectual property rights. Unfortunately, for this sample the results are not significant.

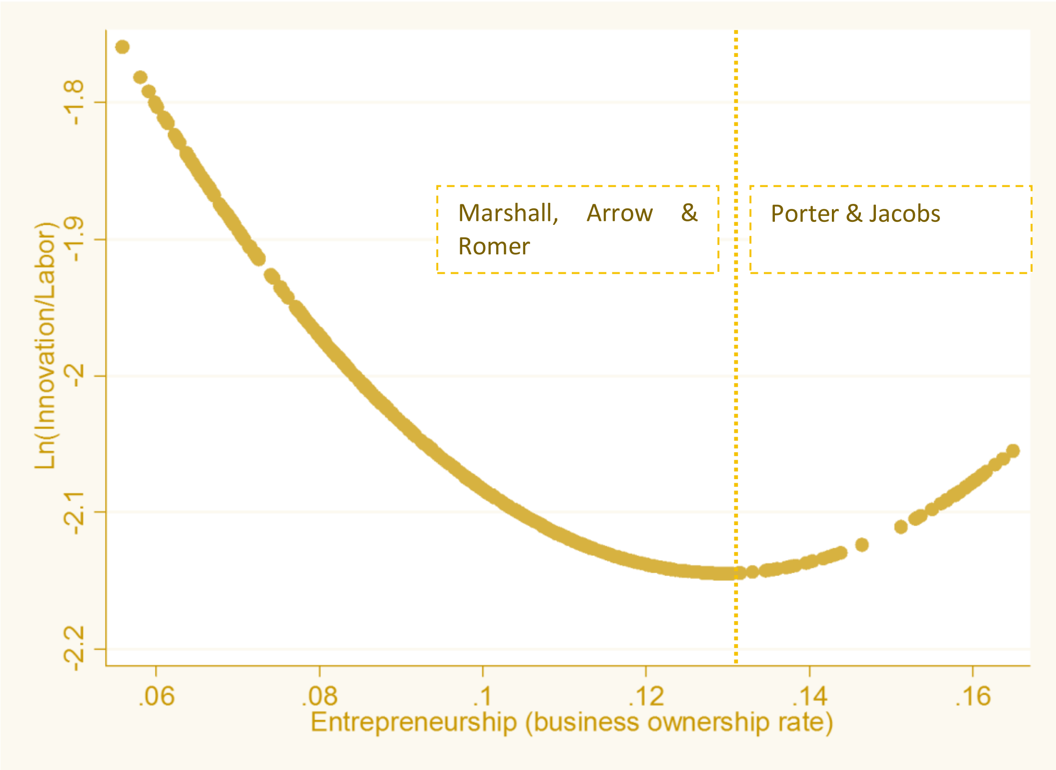

FIGURE 8: RELATIONSHIP BETWEEN ENTREPRENEURSHIP (BUSINESS OWNERSHIP RATE) AND LN(INNOVATION/LABOR). NOTE: THE FIGURE IS BASED ON THE ESTIMATES OF EQUATION 2 IN TABLE 9.

In models (3) and (4) an additional term is included to capture the interaction between entrepreneurship and expenditures on R&D. The idea of the interaction term is that entrepreneurship depends on the level of R&D and vice versa. The interaction effect found here is both negative and significant in the estimated models. This indicates that higher expenditures on R&D have a negative effect on the impact of entrepreneurship on innovation. A possible explanation for this finding lies in the opinions of Schumpeter. Schumpeter argues that entrepreneurs are pre-eminently excellent in the commercialization of new inventions, something that is a crucial part of innovations. R&D however is an input factor, something which helps to create the invention which has to be turned into an innovation later. The fact that the entrepreneur has excellent commercialization skills does not mean that he is also good at creating the invention. In line with the KTSE-theory: entrepreneurs use the knowledge created by incumbents and consequently start their business with this knowledge.[60]

One remark should be made here, namely on the measurement of entrepreneurship. The measurement in this thesis is the business ownership rate, a static measure of entrepreneurship. It measures incumbents. Schumpeterian entrepreneurship is often assumed as new firms (start-ups), a dynamic measurement. In the present study new and incumbents are combined. It was visible in figure 7 that the negative effect for innovative output of BOR dominates the trade-off. This indicates an increasing amount of spillovers but not an incentive to innovate yourself. It is not attractive yet for enterprises to innovate themselves. It might be that when using a different measurement, for example Total Entrepreneurial Activity, the positive link between innovation output and entrepreneurship would more direct. This is, in the business ownership rate, a large majority represents self-employed who are not innovative or entrepreneurial in the Schumpeterian sense. They might not want to grow or may never bring a new innovation to the market (Henrekson & Sanandaji, 2013). Further research can focus on finding a measure for entrepreneurship which captures Schumpeterian entrepreneurship more separately.

[60] The entrepreneur can however be the same person as the inventor, but the theory focuses mainly on the idea that the invention is not created within the same company as in which it is commercialized.

This concludes the discussion on the second equation. This equation is important for the model because it is crucial in filling a gap in the literature. A very small number of studies have focused on the direct determinants of innovation and let alone in the context of economic growth frameworks. The evidence provided here indicates positive relations between intellectual property rights, R&D as well as GDP/labor with innovative output. This verified the assumptions of the theoretical chapter on concepts as the knowledge filter. Even more important was the finding of the U-shaped relation between innovation per laborer and entrepreneurship. This indicates that countries need a certain level of entrepreneurship in order to be able to really profit from them. By using the role that competition plays an important explanation is provided which can be researched further. The addition of this second equation means that for the first time specific elements of the knowledge spillover theory of entrepreneurship is put to the test. The theory has as one of the main assumptions that the role of entrepreneurship for economic growth goes through innovation, but this has never been tested explicitly. The models up to now have added entrepreneurship just as a factor in the economic growth equation, neglecting the important role that it plays for innovation which is part of the KTSE theory.

Together these first results indicate a different role played by entrepreneurship for economic output (static efficiency), as measured in this paper by GDP/Labor, compared to the role played for innovation (dynamic efficiency), measured by the number of patents.

6.4 Robustness checks

Every research needs several robustness checks in order to see if the results hold. Several tests were already provided in the section above in order to explain the effect of education as well as the role of intellectual property rights on innovation. These results can be found in the appendix. Two additional tests are provided here. First, the regressions are generated once more, this time for two time periods: 1981-1995 and 1996-2011. Second, the model is extended with a third equation representing entrepreneurship.

6.4.1 Two time periods

The first robustness test focuses on the question whether the results are driven by a certain subperiod of the time series sample. By providing this robustness check, I want to answer the question if the structure of the macroeconomic production process is stable over time. I therefore divide the sample into two large subperiods: 1981-1995 and 1996-2011. For these subperiods, I present both the results for the GDP/Labor and the innovation regression in the four tables below.

Dependent variable: Ln(GDP/Labor)				
	(1)	(2)	(3)	(4)
Constant	5.086***	5.108***	3.843***	3.868***
	(1.068)	(1.065)	(0.938)	(0.932)
Ln(Capital/labor)	0.463***	0.459***	0.516***	0.512***
	(0.061)	(0.061)	(0.058)	(0.058)
Ln(Labor)	-0.072	-0.075	0.008	0.004
	(0.064)	(0.064)	(0.055)	(0.055)
	$\hat{\beta}$ =0.465	$\hat{\beta}$ =0.466	$\hat{\beta}$ =0.492	$\hat{\beta}$ =0.492
Ln(Innovation)	0.144***	0.143***	0.134***	0.132***
	(0.022)	(0.022)	(0.030)	(0.030)
Education	0.174***	0.182***	0.166***	0.174***
	(0.048)	(0.049)	(0.048)	(0.049)
Entrepreneurship	-0.354	1.036	1.544	2.969
	(0.360)	(1.930)	(1.280)	(2.109)
Entrepreneurship^2		-7.048		-7.641
		(9.604)		(9.316)
Entrepreneurship*Ln(Innovation)			-0.308	-0.294
			(0.208)	(0.207)
Number of observations	255	255	255	255
Optimal Entrepreneurship rate				
Within R^2	0.8176	0.8190	0.8304	0.8320
Rho	0.980	0.980	0.982	0.981
F-value	153.94	154.45	130.14	130.34

TABLE 10: REGRESSION RESULTS EXPLAINING LN(GDP/LABOR), 17 COUNTRIES BETWEEN 1981-1995 USING FIXED EFFECTS ESTIMATION.

A) ESTIMATION METHOD IS TWO-STAGE LEAST SQUARES, FIXED EFFECTS
B) SIGNIFICANTLY DIFFERENT FROM ZERO AT P<0.01 IS DENOTED BY ***, P<0.05 IS DENOTED BY **, P<0.1 IS DENOTED BY *
C) STANDARD ERRORS ARE PRESENTED IN PARENTHESES
D) INNOVATION IS ENDOGENOUS
E) ENTREPRENEURSHIP, EDUCATION, LABOR, CAPITAL-LABOR RATIO, R&D, UNIVERSITY-INDUSTRY RELATIONS AND IP PROTECTION ARE USED AS INSTRUMENTS

Dependent variable: Ln(GDP/Labor)				
	(1)	(2)	(3)	(4)
Constant	6.289***	6.114***	3.727***	3.909***
	(0.646)	(0.672)	(0.575)	(0.576)
Ln(Capital/labor)	0.301***	0.309***	0.222***	0.219***
	(0.646)	(0.048)	(0.059)	(0.059)
Ln(Labor)	-0.008	0.014	0.259***	0.237***
	(0.063)	(0.067)	(0.060)	(0.060)
	$\hat{\beta}$ =0.707	$\hat{\beta}$ =0.705	$\hat{\beta}$ =1.037	$\hat{\beta}$ =1.018
Ln(Innovation)	0.145***	0.154***	0.316***	0.304***
	(0.032)	(0.033)	(0.066)	(0.062)
Education	0.065	0.047	0.084**	0.100**
	(0.042)	(0.044)	(0.042)	(0.041)
Entrepreneurship	1.856***	-1.499	15.493***	17.651***
	(0.422)	(2.230)	(3.072)	(4.458)
Entrepreneurship^2		16.267		-12.150
		(10.935)		(11.807)
Entrepreneurship*Ln(Innovation)			-2.075***	-2.022***
			(0.446)	(0.423)
Number of observations	272	272	272	272
Optimal Entrepreneurship rate				
Within R^2	0.6157	0.6012	0.5783	0.5960
Rho	0.980	0.984	0.995	0.995
F-value	144.86	138.25	91.43	91.93

TABLE 11: REGRESSION RESULTS EXPLAINING LN(GDP/LABOR), 17 COUNTRIES BETWEEN 1996-2011 USING FIXED EFFECTS ESTIMATION.

A) ESTIMATION METHOD IS TWO-STAGE LEAST SQUARES, FIXED EFFECTS
B) SIGNIFICANTLY DIFFERENT FROM ZERO AT P<0.01 IS DENOTED BY ***, P<0.05 IS DENOTED BY **, P<0.1 IS DENOTED BY *
C) STANDARD ERRORS ARE PRESENTED IN PARENTHESES
D) INNOVATION IS ENDOGENOUS
E) ENTREPRENEURSHIP, EDUCATION, LABOR, CAPITAL-LABOR RATIO, R&D, UNIVERSITY-INDUSTRY RELATIONS AND IP PROTECTION ARE USED AS INSTRUMENTS

From table 10 and 11, a comparison can be made between the two subperiods for the models explaining economic growth. Over time, the relative share of the capital input decreases. The relative input of labor on the other hand seems to increase. The influence of innovation on economic growth remains around 0.14 in all models. Most interesting is that entrepreneurship is not significant in any model for the period between 1981 and 1995. For the second period however, it becomes significant at a higher significance level. A possible explanation might be in the so-called shift from the *managed* to the *entrepreneurial economy* (*e.g.* Thurik *et al.*, 2013; Audretsch & Thurik, 2001). The managed economy was the period in which the large enterprises formed the standard. Both in Europe and in the United States the presence and role of large enterprises increased further during the 1980s (Brock & Evans, 1989). Audretsch and Thurik (2001) describe this era as the time of stability, continuity and homogeneity. While in the managed economy the economic performance had a positive relationship with firm size and scale economics, the entrepreneurial economy was characterized as an economy where the performance was more related towards innovation. In this economy innovative, the emergence of entrepreneurial firms, and their consequent growth, creates economic growth. The entrepreneurial economy came to rise in the late 1980s/early 1990s (Wennekers, Carree, Van Stel, & Thurik, 2010). In the entrepreneurial economy, the policies are designed to facilitate more entrepreneurship. It is the general belief that entrepreneurship creates more economic growth and therefore also policies are aimed at facilitating commercialization and creativity among entrepreneurial firms to help them become innovative. In my dataset the shift towards the entrepreneurial economy can also be deducted given that I find that entrepreneurship does play a role in the later time period.

Tables 12 and 13 show the results for the two different time periods for the innovation equation. The tables show the same picture as far as entrepreneurship is concerned for the two different time periods. Also here entrepreneurship becomes significant in the second time period. The results do not indicate a U-shape between innovation per laborer and entrepreneurship for these two shorter time periods. Furthermore, it is interesting to see that the coefficient size for research and development decreases from around 0.7 to around 0.5. This indicates that more knowledge is left in the knowledge filter in the second time period. Also notable is the positive indication of the interaction term between R&D and entrepreneurship in both separate time periods. This in contradiction to when the whole sample is taken and the results indicate a negative (significant) coefficient for the interaction term. The positive results can be explained by the idea that an entrepreneur provides the commercialization skills necessary to turn the R&D into a real product which can be patented. Turning R&D into innovation becomes less straightforward in modern economies.

Dependent variable: Ln(Innovation/Labor)				
	(1)	(2)	(3)	(4)
Constant	-16.642***	-16.204***	-5.859	-4.933
	(4.635)	(4.752)	(3.685)	(3.759)
Ln(Research & Development)	0.715***	0.723***	0.641***	0.655***
	(0.113)	(0.115)	(0.084)	(0.085)
University-Industry Relations	0.784*	0.775*	-0.520	-0.548*
	(0.410)	(0.410)	(0.321)	(0.319)
Ln(IP protection)	-0.634***	-0.622***	-0.535***	-0.512***
	(0.202)	(0.203)	(0.152)	(0.151)
Ln(GDP/Labor)	1.304***	1.251***	0.769***	0.665**
	(0.361)	(0.380)	(0.280)	(0.292)
Ln(Labor)	-0.586**	-0.603**	-1.106***	-1.145***
	(0.236)	(0.239)	(0.185)	(0.186)
	$\hat{\beta}$ =0.414	$\hat{\beta}$ =0.397	$\hat{\beta}$ =-0.106	$\hat{\beta}$ =-0.145
Education	-0.512**	-0.481**	-0.505***	-0.448***
	(0.225)	(0.233)	(0.168)	(0.173)
Entrepreneurship	0.779	5.176	-30.054***	-21.968***
	(1.522)	(8.027)	(2.749)	(6.241)
Entrepreneurship^2		-22.562		-42.879
		(40.571)		(30.217)
Entrepreneurship*Ln(R&D)			5.038***	5.083***
			(0.403)	(0.401)
Number of observations	255	255	255	255
Optimal Entrepreneurship rate				
Within R^2	0.6243	0.6266	0.7905	0.7954
Rho	0.969	0.968	0.913	0.904
F-value	160.52	159.48	61.07	61.68

TABLE 12: REGRESSION RESULTS EXPLAINING LN(INNOVATION/LABOR), 17 COUNTRIES BETWEEN 1981-1995 USING FIXED EFFECTS ESTIMATION.

- **A) ESTIMATION METHOD IS TWO-STAGE LEAST SQUARES, FIXED EFFECTS**
- **B) SIGNIFICANTLY DIFFERENT FROM ZERO AT P<0.01 IS DENOTED BY ***, P<0.05 IS DENOTED BY **, P<0.1 IS DENOTED BY ***
- **C) STANDARD ERRORS ARE PRESENTED IN PARENTHESES**
- **D) GDP/LABOR IS ENDOGENOUS**
- **E) R&D, UNIVERSITY-INDUSTRY RELATIONS, IP PROTECTION, EDUCATION, ENTREPRENEURSHIP, LABOR, AND THE CAPITAL-LABOR RATIO ARE USED AS INSTRUMENTS**

Dependent variable: Ln(Innovation/Labor)				
	(1)	(2)	(3)	(4)
Constant	-9.443*	-9.400*	-1.350	-1.756
	(5.444)	(5.404)	(3.277)	(3.234)
Ln(Research & Development)	0.506***	0.501***	0.172*	0.224**
	(0.159)	(0.168)	(0.101)	(0.104)
University-Industry Relations	-0.590	-0.579	0.144	-0.274
	(0.812)	(0.820)	(0.497)	(0.497)
Ln(IP protection)	1.884***	1.892***	0.821**	0.687*
	(0.603)	(0.605)	(0.373)	(0.372)
Ln(GDP/Labor)	0.808	0.804	1.120***	1.180***
	(0.538)	(0.533)	(0.332)	(0.326)
Ln(Labor)	-0.921***	-0.925***	-1.742***	-1.711***
	(0.309)	(0.310)	(0.192)	(0.191)
	$\hat{\beta}$ =0.079	$\hat{\beta}$ =0.075	$\hat{\beta}$ =-0.742	$\hat{\beta}$ =-0.711
Education	0.100	0.105	-0.077	-0.162
	(0.184)	(0.187)	(0.114)	(0.115)
Entrepreneurship	-5.550***	-4.364	-44.285***	-60.530***
	(1.836)	(9.788)	(2.252)	(6.476)
Entrepreneurship^2		-5.681		74.709***
		(46.588)		(28.369)
Entrepreneurship*Ln(R&D)			6.180***	6.303***
			(0.304)	(0.304)
Number of observations	272	272	272	272
Optimal Entrepreneurship rate				
Within R^2	0.4540	0.4542	0.7974	0.8010
Rho	0.970	0.971	0.996	0.995
F-value	125.47	117.38	57.89	54.49

TABLE 13: REGRESSION RESULTS EXPLAINING LN(INNOVATION/LABOR), 17 COUNTRIES BETWEEN 1996-2011 USING FIXED EFFECTS ESTIMATION.

- **A) ESTIMATION METHOD IS TWO-STAGE LEAST SQUARES, FIXED EFFECTS**
- **B) SIGNIFICANTLY DIFFERENT FROM ZERO AT P<0.01 IS DENOTED BY ***, P<0.05 IS DENOTED BY **, P<0.1 IS DENOTED BY ***
- **C) STANDARD ERRORS ARE PRESENTED IN PARENTHESES**
- **D) GDP/LABOR IS ENDOGENOUS**
- **E) R&D, UNIVERSITY-INDUSTRY RELATIONS, IP PROTECTION, EDUCATION, ENTREPRENEURSHIP, LABOR, AND THE CAPITAL-LABOR RATIO ARE USED AS INSTRUMENTS**

6.4.2 ENDOGENEITY OF ENTREPRENEURSHIP

One argument, made in the literature several times (*e.g.* Audretsch & Keilbach, 2004a; Van Praag & Van Stel, 2013) is that there might be endogeneity in the relationship between entrepreneurship and economic growth. This is the idea that entrepreneurship also creates an endogeneity problem causing a simultaneity bias in the regressions. The idea behind this is that not only does entrepreneurship cause economic growth, but also does economic growth attract entrepreneurship. More growth means more opportunities which can attract entrepreneurs. The same reasoning might hold for innovation. Audretsch, Bönte & Keilbach (2008) suggest this relationship. They argue that investments in innovation or new knowledge lead to an increase in entrepreneurial opportunities and hence entrepreneurship. Areas which have higher endowments of knowledge will then also experience higher levels of entrepreneurship. Their hypothesis is thus: *"Regional innovation efforts have a positive impact on regional knowledge based entrepreneurial activity."* (Audretsch, Bonte, & Keilbach, 2008, p. 689).

To solve possible consequences of this endogeneity, an additional equation is added to my model which estimates entrepreneurship. Following the same approach as Van Praag & Van Stel (2013), this equation is as follows:

$$E_{it} = \kappa_i + \lambda_1 Age\ share_{it} + \lambda_2 Rural\ population_{it} + \lambda_3\, \Delta\left(\frac{Y}{L}\right)_{it} + \nu_{it} \tag{47}$$

Here, three factors are used which are known to influence entrepreneurship but not GDP/labor (Audretsch, Thurik, Verheul & Wennekers, 2002). The first is the share of the population aged 25–39 years within the population aged 25-64 years, obtained from the United Nations Population Information Network (POPIN): World Population Prospects (2012 revision). The variable is expressed in percentages. Studies have shown that when people are in this age, they are most likely to undertake entrepreneurial activities (Storey, 2003). The second is the share (in %) of the population living in rural areas, obtained from the World Bank. Lastly, the growth rate in percentages from GDP per laborer is introduced. This growth rate is estimated based on the GDP and labor variables which are included in my dataset.[61]

Looking at the results, I can discuss both equations at the same time.[62] This is because almost no changes occur to the results discussed before after adding this third equation to the model. The only difference is that the labor variable loses its significance in model (3) of the innovation equation. The other variables only show some differences in the size of the coefficients. The fact that both results are the same might indicate that the possible simultaneity bias that does exists, does little or not affect the estimations. Another reason is that the reversed causality of economic growth on entrepreneurship is not likely because the dependent variable is measured in levels instead of growth levels. This means that the argument that fast-growing countries will attract more entrepreneurs does not apply in this case. For the innovation equation, the U-shaped relation between innovation and entrepreneurship is also found. It is a positive point that the turning point of the equation remains exactly the same. Based on the results of this model, and especially the similarity between the results, I deduct that no reverse causality issue is at play and that the results which were found are indeed likely to represent causal relationships.

[61] See subsection 5.3 "Data" for the source of labor and GDP statistics.
[62] The results of the third equation and first stages are not presented here.

Dependent variable: Ln(GDP/Labor)				
	(1)	(2)	(3)	(4)
Constant	5.583***	5.533***	5.006***	4.953***
	(0.412)	(0.411)	(0.377)	(0.376)
Ln(Capital/labor)	0.455***	0.457***	0.453***	0.457***
	(0.029)	(0.029)	(0.031)	(0.030)
Ln(Labor)	-0.106***	-0.104***	-0.048	-0.048
	(0.031)	(0.031)	(0.032)	(0.032)
	= 0.439	= 0.439	= 0.499	= 0.495
Ln(Innovation)	0.106***	0.104***	0.118***	0.114***
	(0.014)	(0.014)	(0.019)	(0.019)
Education	0.210***	0.211***	0.219***	0.220***
	(0.023)	(0.023)	(0.023)	(0.023)
Entrepreneurship	1.056***	1.533	3.214***	3.882**
	(0.228)	(1.259)	(0.958)	(1.679)
Entrepreneurship^2		-2.348		-4.027
		(6.118)		(6.188)
Entrepreneurship*Ln(Innovation)			-0.318**	-0.295**
			(0.139)	(0.138)
Number of observations	527	527	527	527
Optimal Entrepreneurship rate		0.326		
Within R^2	0.8916	0.8921	0.8913	0.8922
Rho	0.938	0.938	0.927	0.927
F-value	168.01	167.65	168.34	168.74

TABLE 14: REGRESSION RESULTS EXPLAINING LN(GDP/LABOR), 17 COUNTRIES BETWEEN 1981-2011 USING FIXED EFFECTS ESTIMATION.

- A) ESTIMATION METHOD IS TWO-STAGE LEAST SQUARES, FIXED EFFECTS
- B) SIGNIFICANTLY DIFFERENT FROM ZERO AT P<0.01 IS DENOTED BY ***, P<0.05 IS DENOTED BY **, P<0.1 IS DENOTED BY *
- C) STANDARD ERRORS ARE PRESENTED IN PARENTHESES
- D) INNOVATION AND ENTREPRENEURSHIP ARE ENDOGENOUS
- E) ENTREPRENEURSHIP, EDUCATION, LABOR, CAPITAL-LABOR RATIO, R&D, UNIVERSITY-INDUSTRY RELATIONS, IP PROTECTION, AGE SHARE, RURAL POPULATION AND GROWTH RATE OF GDP/LABORER ARE USED AS INSTRUMENTS

Dependent variable: Ln(Innovation/Labor)				
	(1)	(2)	(3)	(4)
Constant	-10.484***	-9.903***	-11.503***	-10.879***
	(1.992)	(1.986)	(2.034)	(2.034)
Ln(Research & Development)	0.700***	0.744***	0.754***	0.792***
	(0.055)	(0.056)	(0.058)	(0.059)
University-Industry Relations	-0.220	0.021	-0.077	0.138
	(0.352)	(0.359)	(0.355)	(0.361)
Ln(IP protection)	0.326**	0.200	0.362***	0.241*
	(0.132)	(0.138)	(0.131)	(0.138)
Ln(GDP/Labor)	0.664***	0.699***	0.593***	0.623***
	(0.187)	(0.186)	(0.185)	(0.184)
Ln(Labor)	-0.583***	-0.629***	-0.441***	-0.496***
	(0.110)	(0.110)	(0.123)	(0.124)
Education	-0.038	-0.038	-0.005	-0.008
	(0.103)	(0.102)	(0.102)	(0.102)
Entrepreneurship	-3.978***	-18.491***	4.896	-9.452
	(0.868)	(4.952)	(3.603)	(6.246)
Entrepreneurship^2		71.884***		67.501***
		(24.159)		(24.071)
Entrepreneurship*Ln(R&D)			-1.013**	-0.931***
			(0.398)	(0.397)
Number of observations	527	527	527	527
Optimal Entrepreneurship rate		0.129		0.07
Within R^2	0.8121	0.8150	0.8152	0.8177
Rho	0.953	0.954	0.961	0.960
F-value	226.03	223.5	228.63	225.08

TABLE 15: REGRESSION RESULTS EXPLAINING LN(INNOVATION/LABOR), 17 COUNTRIES BETWEEN 1981-2011 USING FIXED EFFECTS ESTIMATION.

A) **ESTIMATION METHOD IS TWO-STAGE LEAST SQUARES, FIXED EFFECTS**
B) **SIGNIFICANTLY DIFFERENT FROM ZERO AT P<0.01 IS DENOTED BY ***, P<0.05 IS DENOTED BY **, P<0.1 IS DENOTED BY ***
C) **STANDARD ERRORS ARE PRESENTED IN PARENTHESES**
D) **GDP/LABOR AND ENTREPRENEURSHIP ARE ENDOGENOUS**
E) **R&D, UNIVERSITY-INDUSTRY RELATIONS, IP PROTECTION, EDUCATION, ENTREPRENEURSHIP, LABOR, THE CAPITAL-LABOR RATIO, AGE-SHARE, RURAL POPULATION AND THE GROWTH OF GDP PER LABORER ARE USED AS INSTRUMENTS**

6.5 WRAP-UP

This section contains the essence of the paper. Using several different estimations of the simultaneous equation models, some interesting results were provided. The results do provide evidence for the KTSE-theory, more robust and complete than what was found before. I found that entrepreneurs are indeed involved in creating innovations and in generating economic growth. Entrepreneurship has a positive, direct effect on economic growth. This effect might be due to competition or diversity which the entrance of a new firm brings to the economy. The most interesting finding was that a U-shaped relation seems to exist between innovation and entrepreneurship. Only after a certain threshold the positive influence of entrepreneurship occurs. A possible explanation was provided by relating competition and incentives to innovate with each other. For low levels of entrepreneurship, the effect of entrepreneurship on innovation is negative, because the incentives to innovate decrease due to new knowledge spilling over to competitors. For higher levels, this fear is less relevant because firms are forced to innovate in order to stay competitive and stay in the market. This connection between incentives and competition has not been made so explicitly before in an empirical model. Lastly, evidence was also provided for the positive influence of intellectual property rights on innovation and the existence on the knowledge filter. The existence of the knowledge filter, although a well-known theoretical topic, was proven based on the influence of R&D on innovation. Also, the importance of traditional elements for economic growth (capital, labor, education) was confirmed.

7 CONCLUSION

In this paper, I provided evidence for the direct and indirect effect of entrepreneurship on economic growth. This evidence provides support for the Knowledge Spillover Theory of Entrepreneurship. The central and crucial role of entrepreneurship for economic growth is highlighted using the simultaneous equation model. I argue based on the results that entrepreneurship is a basic factor of production which has a positive influence on economic growth. The influence of entrepreneurship on innovation however is not as straightforward while the impact of innovation on economic growth is confirmed. Entrepreneurs who put in effort to introduce new innovation are important conduits for knowledge spillovers.

In order to test both hypotheses on the relationship between economic growth and entrepreneurship, a simultaneous equation model was applied. The first hypothesis focused on the direct relationship between entrepreneurship and economic growth stating that such a relationship is present, linear and positive. The second hypothesis focused on the indirect relationship with innovation as the intermediate factor. Both have in common the assumption of the positive role that entrepreneurship can play and both were verified in the estimated models. Although, the relationship between innovation and entrepreneurship seemed to be U-shaped. This indicated that only after a certain turning point the influence of more entrepreneurship on innovation is positive.

This study provided the first empirical tests of one of the crucial assumptions of the knowledge spillover theory of entrepreneurship. Prior, one focused on extending the theory (*e.g.* Qian & Acs (2013) add absorptive capacity of entrepreneurship; Audretsch & Belitski (2013) add creativity as a factor) or providing a more in-depth mathematical build-up (*e.g.* Acs & Sanders (2013) who provide an in-depth micro-economic build for the theory). How important these additions may be, they disregard empirical evidence on the relationship between entrepreneurship and innovation. This is exactly the gap that this paper fills: showing how innovation and entrepreneurship are related. Not only that, I add to the literature with a new dataset for a longer period of time and with new and different control variables. This paper thoroughly establishes both the direct and indirect effect of entrepreneurship for economic growth.

The results from both equations indicate that entrepreneurship increases innovation output to a large extent, from a turning point onwards, while innovation output in turn is positively associated with economic growth. An interesting finding in that light was the U-shaped relationship between innovation and entrepreneurship leading to the discussion on possible reasons for the initial negative effect up to the turning point after which the influence of entrepreneurship is positive. No such relationship was found between entrepreneurship and economic growth, leading to the finding that the direct positive effect is linear. So in short, I find that entrepreneurship both has direct and indirect effects on economic growth while I also find that a country needs a strong knowledge stock.

A further contribution is the careful distinction made in the paper between innovation output (*e.g.* patents) and innovation input (*e.g.* R&D). This distinction is important because not all R&D is economically valuable. It is innovation output rather than innovation input that in the end helps to increase economic prosperity. While estimating both equations, evidence was also provided on the knowledge filter, a concept related to the difference between innovation inputs and outputs. I showed that all input, in terms of Research and Development, is not one on one translated into innovation output. A one percent increase in R&D does not lead to a one percent increase in innovation but only around 75% is translated into innovation, so around 25% is left behind in the knowledge filter. This means that to a certain extent these investments do not make it into an innovation directly while they are expected to generate knowledge. This illustrates the working of the knowledge filter. Within the filter the knowledge remains available and it can possibly be used again for a different application. Another finding was the significant influence of intellectual property rights on innovation.

The results could have some consequences for further research and some policy implications which I will discuss now.

Policy implications

The results suggest that in developed, knowledge-based economies, like in my sample, the policy focus should not be solely on the generation of knowledge. The generation of knowledge is not enough, because entrepreneurship can play a large and positive role as well. It can provide the transformation between knowledge and innovation. Countries which have high R&D expenditures do not necessarily also have high growth rates. This is what I referred to earlier as the European Paradox.[63] Attention should also be on the conduit which helps to transfer knowledge into innovation and ultimately growth. Entrepreneurship was suggested as the required conduit to help this transformation take place. Policy makers can encourage the commercialization of knowledge by encouraging entrepreneurs. This can encourage in turn the conversion of knowledge into new products or technologies. Of course, the new knowledge should then also be available to the entrepreneur.

This all might shift the focus of traditional entrepreneurship policy measures, often aimed at providing risk capital or an infrastructure for the start-ups, towards a more knowledge oriented approach. Venkataraman (2004) for instance proposes that intangibles are especially important. He mentions role models, informal forums, safety nets as examples of such measures. He views this as a difficult process which takes some time and needs the supported by the close collaboration of governments, universities, firms and other public or private institutions.

Another benefit of focusing on entrepreneurship is the result that also the positive direct effect of entrepreneurship on economic growth can materialize. This is, entrepreneurship not only helps to generate innovations after some point, but will influence economic growth also in a more direct manner. Focusing on increasing entrepreneurship thus kills two birds with one stone. Competition (*i.e.* more entrepreneurship) stimulates firms to use their resources in an efficient way as well as that more firms will facilitate more knowledge spillovers. Nevertheless it is important to realize that entrepreneurship plays a different role for economic growth (static efficiency) as for innovation (dynamic efficiency).

However, policy makers should not focus solely on entrepreneurship but realize that a combination of policies is necessary. Indeed, entrepreneurs need resources for their opportunities which require knowledge flows in the economy. Further research should help unravel the perfect combination of inputs.

Further research

This paper is innovative in several ways: it introduced a new dataset that contains many years of data available to analyze the interplay between entrepreneurship, innovation and economic growth. Also, it is the first to explicitly model and research the relationship between entrepreneurship and innovation. Although the close connection between the two is one of the main hypotheses of the Knowledge Spillover Theory of Entrepreneurship, research so far has only modeled the direct influence of entrepreneurship on economic growth and supposed that this relationship could be explained by innovation. This paper is among the first to systematically model the relation between innovation and entrepreneurship separately.

However, as any research, this paper also has some limitations and pointers for further research. First, the direct effect of entrepreneurship on economic growth should be disentangled further. Potential directions are to research if the effect can be explained by diversity, competition or specialization effects. An interesting starting point for this debate can be found in the theories of the MAR (Marshall, Arrow, and Romer) economists, Porter and Jacobs.

Another potential lies in applying the same model on the regional level. Many papers have focused on economic growth in regions nowadays, but here also the direct relationship between entrepreneurship and innovation is

[63] The phenomenon that Europe has large investments on knowledge on the one hand but that this does not translate into high growth rates on the other. See also European Commission (1995).

lacking as a line of research. When focusing more on the regional level there might also be a higher potential for researching the university-industry angle of incidence. Theoretically, this connection makes a lot of sense and also other papers (*e.g.* Mueller, 2006) have provided evidence for the existence.

Furthermore, research can try to expand the model focusing more on the trade-off created by intellectual property rights. This paper found that intellectual property rights have a positive influence on innovation while theoretically I argued that a trade-off takes place. This is the trade-off between the incentive to innovate and the access to the knowledge filter. Preliminary tests in this paper trying to find this turning point have not provided significant results. Further research might investigate this theory and set-up additional research efforts. For example by developing new research on countries which differ more in protection laws or focus on different periods in time.

One of the largest limitations of this study is the measure of entrepreneurship. In theory a strong case was built for the behavioral notion of entrepreneurship. The measure used in this thesis however was based on a static notion which represents the number of firms in the economy. The consequence is that the link between entrepreneurship and innovation is less direct because this measure will also cover many non-innovative enterprises. Second, it includes both new and incumbent firms, which is not in line with the Schumpeterian definition as well as the assumption of KTSE. Further research might want to focus on finding and using a measure which answers more to these theoretical needs.

Another direction for further research might be to focus more on what entrepreneurs need to be as productive and important for innovation and economic growth as possible. One option is to use different measures of entrepreneurship which each represent a specific type. For example, Mueller (2007) used innovative start-up capacity as a proxy for entrepreneurship. She found that innovative start-up capacity is more important than raising general start-up activity for economic growth. GEM data might help with this goal, for example by using the TEA (total entrepreneurial activity) measure when it becomes available for more years. By running the same models with different types of entrepreneurship, more detailed directions for policy makers can be provided. This will help to see what type of entrepreneurship has to be especially stimulated to reach the most positive effect for economic prosperity as possible.

The suggestion of using different measures of entrepreneurship is also related to the idea of the absorptive capacity introduced by Cohen & Levinthal (1990) and discussed in the theory section. This concept has been largely ignored in the empirical section of this paper. Entrepreneurs probably need tools and other intangibles to be on top of their game and profit from knowledge spillovers as much as possible. Qian & Acs (2013) have already argued that the performance of entrepreneurs depends on their absorptive capacity. This is the capacity that makes it possible for entrepreneurs to understand new knowledge, realize its value and commercialize it consequently. Further research can try to find the determinants that allow entrepreneurship to be as productive and effective as possible. This can add an extra dimension to the innovation equation and the simultaneous equation as a whole.

Another limitation lies in the measurement of the innovation variable. I used patents granted because this is one of the very few proxies that is available over the long term for many countries. Using this proxy might not be fair towards the entrepreneur of which one can argue that the propensity to patent the inventions, at least in the beginning, is low. Further research should focus on finding a proxy which takes into account both the national results as well as the specifics of a small firm.

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9 Appendix

9.1 Innovation equation: R&D variables

The following table presents the results for the innovation equation. The equations are estimated using two different variables for R&D. The table includes both a variable for public and for private R&D.

	Dependent variable: Ln(Innovation/Labor)	
	(1)	(2)
Constant	-11.527*** (2.126)	-11.622*** (2.124)
Ln(Research & Development in private sector)	0.354*** (0.033)	0.373*** (0.035)
Ln(Research & Development in public sector)	0.218*** (0.059)	0.208*** (0.060)
University-Industry Relations	0.384 (0.355)	0.577 (0.366)
Ln(IP protection)	0.321** (0.139)	0.223 (0.146)
Ln(GDP/Labor)	0.893*** (0.195)	0.962*** (0.198)
Ln(Labor)	-0.567*** (0.119) $\hat{\beta}$ =0.433	-0.579*** (0.119) $\hat{\beta}$ =0.421
Education	-0.048 (0.108)	-0.055 (0.108)
Entrepreneurship	-4.712*** (0.900)	-15.330*** (4.989)
Entrepreneurship^2		52.864** (24.469)
Number of observations	527	527
Optimal Entrepreneurship rate		0.145
Within R^2	0.8105	0.8116
Rho	0.953	0.953
F-value	301.31	293.13

TABLE 16: REGRESSION RESULTS EXPLAINING LN(INNOVATION/LABOR), 17 COUNTRIES BETWEEN 1981-2011 USING FIXED EFFECTS ESTIMATION.

- A) ESTIMATION METHOD IS TWO-STAGE LEAST SQUARES, FIXED EFFECTS
- B) SIGNIFICANTLY DIFFERENT FROM ZERO AT P<0.01 IS DENOTED BY ***, P<0.05 IS DENOTED BY **, P<0.1 IS DENOTED BY *
- C) STANDARD ERRORS ARE PRESENTED IN PARENTHESES
- D) GDP/LABOR IS ENDOGENOUS
- E) R&D, UNIVERSITY-INDUSTRY RELATIONS, IP PROTECTION, EDUCATION, ENTREPRENEURSHIP, LABOR, AND THE CAPITAL-LABOR RATIO ARE USED AS INSTRUMENTS

9.2 INNOVATION EQUATION: IP PROTECTION

The following table includes the results for three models of the innovation equation. The first model is the 'standard' model as also presented in table 9 in the paper above. Model (2) presents the innovation function with a quadratic term for intellectual property rights. The third model includes an interaction term between entrepreneurship and intellectual property rights.

	Dependent variable: Ln(Innovation/Labor)		
	(1)	(2)	(3)
Constant	-9.410***	-10.813***	-10.809***
	(2.144)	(3.309)	(2.255)
Ln(Research & Development)	0.715***	0.686***	0.691***
	(0.056)	(0.074)	(0.057)
University-Industry Relations	-0.241	-0.189	-0.234
	(0.352)	(0.362)	(0.351)
Ln(IP protection)	0.352***	0.970	0.774**
	(0.133)	(0.836)	(0.329)
Ln(GDP/Labor)	0.554***	0.643**	0.569***
	(0.204)	(0.272)	(0.203)
Ln(Labor)	-.0.587***	-0.552***	-0.489***
	(0.110)	(0.122)	(0.129)
	$\hat{\beta}$ =0.412	$\hat{\beta}$ =0.448	$\hat{\beta}$ =0.511
Education	0.001	-0.000	-0.010
	(0.106)	(0.107)	(0.106)
Entrepreneurship	-4.079***	-4.152***	1.747
	(0.869)	(0.869)	(4.154)
Ln(IP protection)^2		-0.249	
		(0.340)	
Entrepreneurship*Ln(IP protection)			-4.319
			(3.027)
Number of observations	527	527	
Optimal IP protection rate		NA	
Within R^2	0.8131	0.8127	
Rho	0.953	0.955	
F-value	224.79	155.24	

TABLE 17: REGRESSION RESULTS EXPLAINING LN(INNOVATION/LABOR), 17 COUNTRIES BETWEEN 1981-2011 USING FIXED EFFECTS ESTIMATION.

- A) ESTIMATION METHOD IS TWO-STAGE LEAST SQUARES, FIXED EFFECTS
- B) SIGNIFICANTLY DIFFERENT FROM ZERO AT P<0.01 IS DENOTED BY ***, P<0.05 IS DENOTED BY **, P<0.1 IS DENOTED BY *
- C) STANDARD ERRORS ARE PRESENTED IN PARENTHESES
- D) GDP/LABOR IS ENDOGENOUS
- E) R&D, UNIVERSITY-INDUSTRY RELATIONS, IP PROTECTION, EDUCATION, ENTREPRENEURSHIP, LABOR, AND THE CAPITAL-LABOR RATIO ARE USED AS INSTRUMENTS

9.3 Innovation equation: with education & without GDP/Labor

The following table presents the results of the estimation of the innovation equation. Special about this model is that it leaves GDP/labor out of the equation as an explanatory variable. Goal of this exercise is to see how education reacts to this new estimation method.

Dependent variable: Ln(Innovation/Labor)				
	(1)	(2)	(3)	(4)
Constant	-4.034***	-3.265***	-5.930***	-5.093***
	(0.831)	(0.871)	(1.064)	(1.106)
Ln(Research & Development)	0.793***	0.838***	0.843***	0.881***
	(0.048)	(0.051)	(0.051)	(0.053)
University-Industry Relations	-0.345	-0.126	-0.171	0.023
	(0.352)	(0.358)	(0.355)	(0.361)
Ln(IP protection)	0.484***	0.372***	0.505***	0.399***
	(0.125)	(0.130)	(0.124)	(0.130)
Ln(Labor)	-0.611***	-0.655***	-0.450***	-0.501***
	(0.110)	(0.111)	(0.123)	(0.124)
Education	0.192**	0.199**	0.201**	0.208***
	(0.080)	(0.080)	(0.080)	(0.080)
Entrepreneurship	-4.583****	-18.110***	5.346	-7.911
	(0.854)	(4.970)	(3.615)	(6.257)
Entrepreneurship^2		66.891***		62.469**
		(24.219)		(24.1317)
Entrepreneurship*Ln(R&D)			-1.125***	-1.054***
			(0.398)	(0.397)
Number of observations	527	527	527	527
Optimal Entrepreneurship rate		0.135		0.063
Within R^2	0.8103	0.8132	0.8133	0.8158
Rho	0.954	0.955	0.963	0.963
F-value	269.94	265.89	273.88	268.88

TABLE 18: REGRESSION RESULTS EXPLAINING LN(INNOVATION/LABOR), 17 COUNTRIES BETWEEN 1981-2011 USING FIXED EFFECTS ESTIMATION.

A) SIGNIFICANTLY DIFFERENT FROM ZERO AT P<0.01 IS DENOTED BY ***, P<0.05 IS DENOTED BY **, P<0.1 IS DENOTED BY *
B) STANDARD ERRORS ARE PRESENTED IN PARENTHESES