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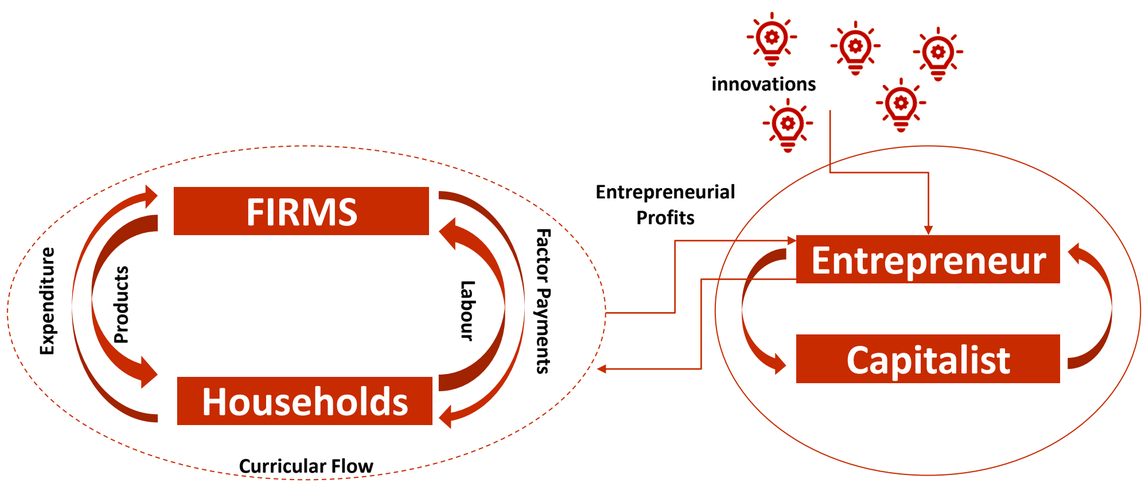
Innovation, Technology, and Growth

Do innovations lead to prosperity and economic growth?

Innovation & Growth Background

Since **Schumpeter** (1912; 1942) introduced his theories about **creative destruction** and **innovation**, there has been a **common understanding** that **innovation** is a **significant driver** of **growth** and **prosperity** (Kogan et al., 2017; Schubert and Simar, 2011).



The benefits of **innovation** in the form of **technology** in the **neoclassical model** originated with **Solow (1956) and Swan (1956).** The economic model uses an aggregate production function of the following form:

$$Y = Af(K, L).$$

in this model, Y denotes gross domestic product, which depends on capital K, labor L, and the level of technology A (Greenhalgh and Rogers, 2010). Using American data from 1909 to 1949, Solow (1957) was able to **show that gross output per person-hour doubled** over the period and **that 87.5%** of this **increase** was due to **technological change** and **only 12.5%** to an **increase in capital.**

The **endogenous growth theory** assumes that long-term growth is driven **primarily by the accumulation** of **knowledge** by forward-looking, profit-maximizing agents (Romer, 1986). The core idea of endogenous growth theory is that when a firm generates new knowledge, some of that new knowledge can help other firms (Greenhalgh and Rogers, 2010):

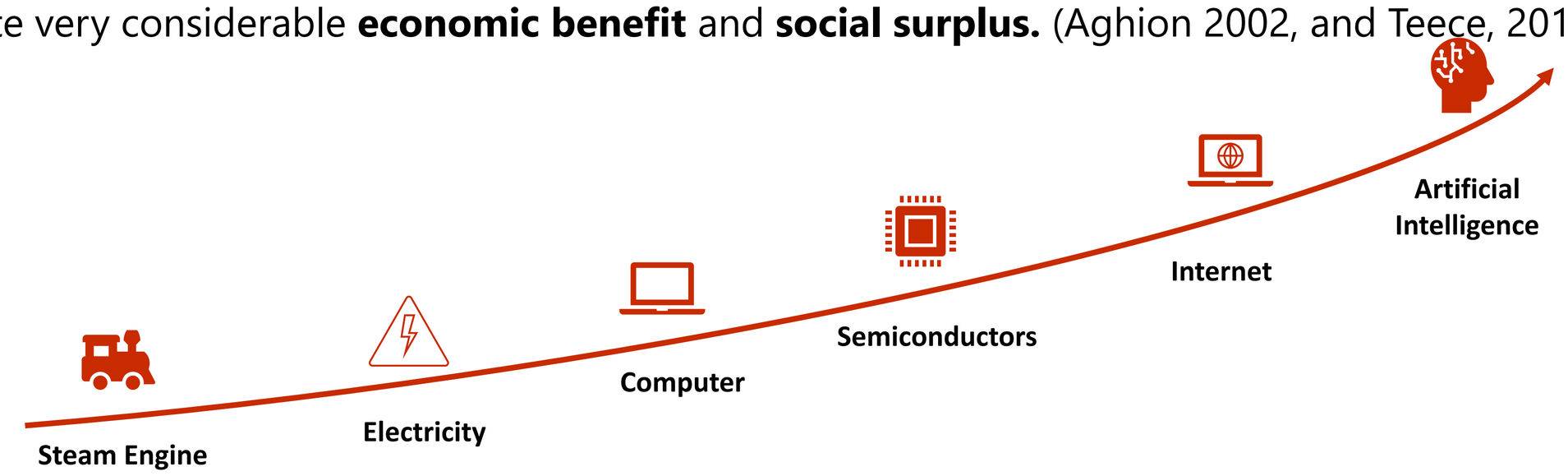
- **Technological change** is at the core of **economic growth**.
- **Technological change arises** in large part from **intentional actions by people responding to market incentives.**
- **Instructions for working with raw materials differ from economic goods**; once the cost of creating a new instruction has been incurred, the instruction can **be used repeatedly without additional cost**.

The implication of these premises is that the technology (or innovation) **component A** is **incorporated directly into the production function as a factor** (Schubert and Simar, 2011), whereby the growth is endogenous in comparison to the neoclassical model:

$$\mathbf{Y = f(A, K, L)}.$$

Innovation, Technology and Growth

A so-called **General-Purpose Technology (GPT)** is a **technological breakthrough** that **affects an entire economic system**, that is, most sectors in an economy. **Examples of GPTs** include the **steam engine**, **the electric dynamo**, **the laser**, and the arrival of the new **information technologies** embodied in information and **communication equipment**. They **can often be disruptive** to the status quo and generate very considerable **economic benefit** and **social surplus.** (Aghion 2002, and Teece, 2018)



Sources: Schumpeter, Joseph (1912): Theorie der wirtschaftlichen Entwicklung. Leibzig: Dunker & Humbolt. Schumpeter, Joseph A. (1942): Capitalism, socialism and democracy. New York, London: Harper. Kogan, Leonid; Papanikolaou, Dimitris; Seru, Amit; Stoffman, Noah (2017): Technological Innovation, Resource Allocation, and Growth. In: The Quarterly Journal of Economics 132 (2), S. 665–712. Solow, Robert M. (1956): A Contribution to the Theory of Economic Growth. In: The Quarterly Journal of Economics 70 (1), S. 65–94. Swan, T. W. (1956): Economic Growth and Capital Accumulation. In: Economic Record 32 (2), S. 334–361. Schubert, Torben; Simar, Léopold (2011): Innovation and export activities in the German mechanical engineering sector: an application of testing restrictions in production analysis. In: J Prod Anal 36 (1), S. 55–69. Aghion, Philippe (2002): Schumpeterian Growth Theory and the Dynamics of Income Inequality. In: Econometrica 70 (3), S. 855–882. Teece, David J. (2018): Profiting from innovation in the digital economy: Enabling technologies, standards, and licensing models in the wireless world. In: Research Policy 47 (8), S. 1367–1387.

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Sustainable Innovation

Do innovation activities and sustainability correlate?

Sustainability Strategies

Recommendations in UN documents and scientific literature on sustainable development can be grouped into **three different strategies** for achieving environmental sustainability:

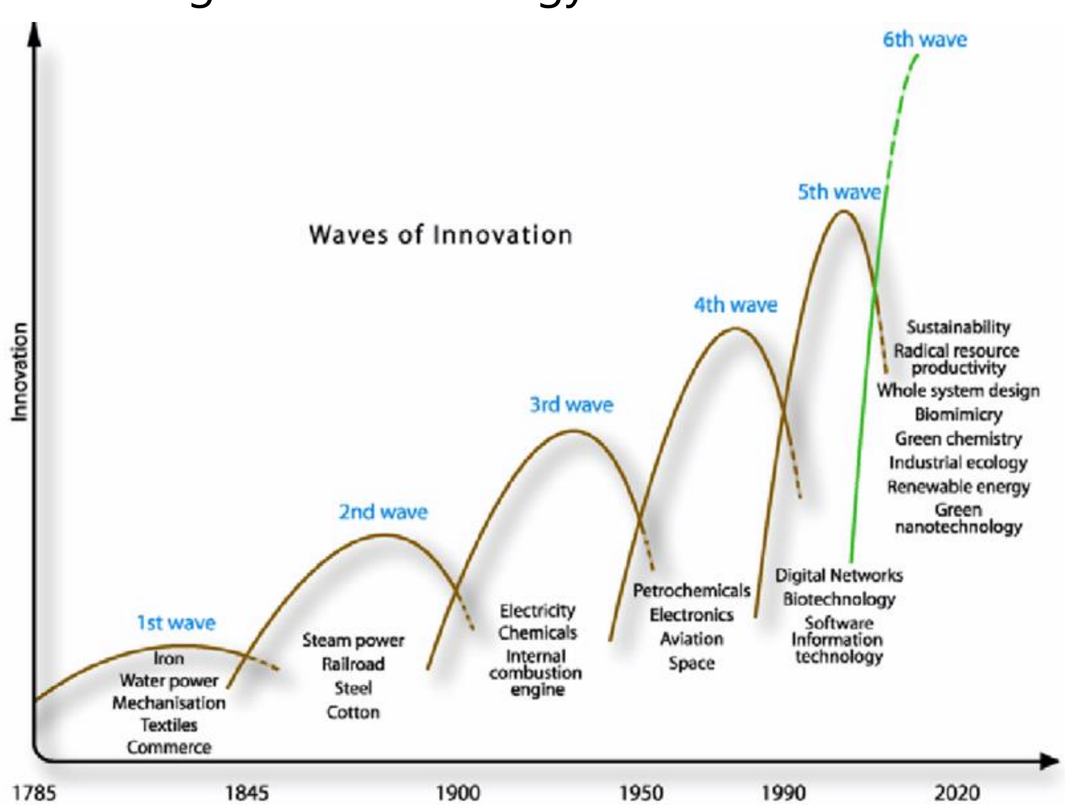
- **Sufficiency (less):** Limitation of usage and renunciation of consumption
- **Efficiency (better):** Improvement of current systems towards a more efficient use of a given amount of resources
- **Consistency (different):** Substitution of current technologies through more eco-friendly alternatives

To follow any of these strategies, companies must change how they operate and innovate their processes, services ,products or business model.

Hence, innovation is essential for sustainable development.

Next Kondratieff Cycle

The Kondratieff Cycle is **long-wave fluctuations in the world economy, based** on new key technologies or technology fields.



Currently, the **next wave is starting based on sustainable and green technologies**. So, companies allocate a lot of research and development in this area.

Innovation as a driver of Sustainability

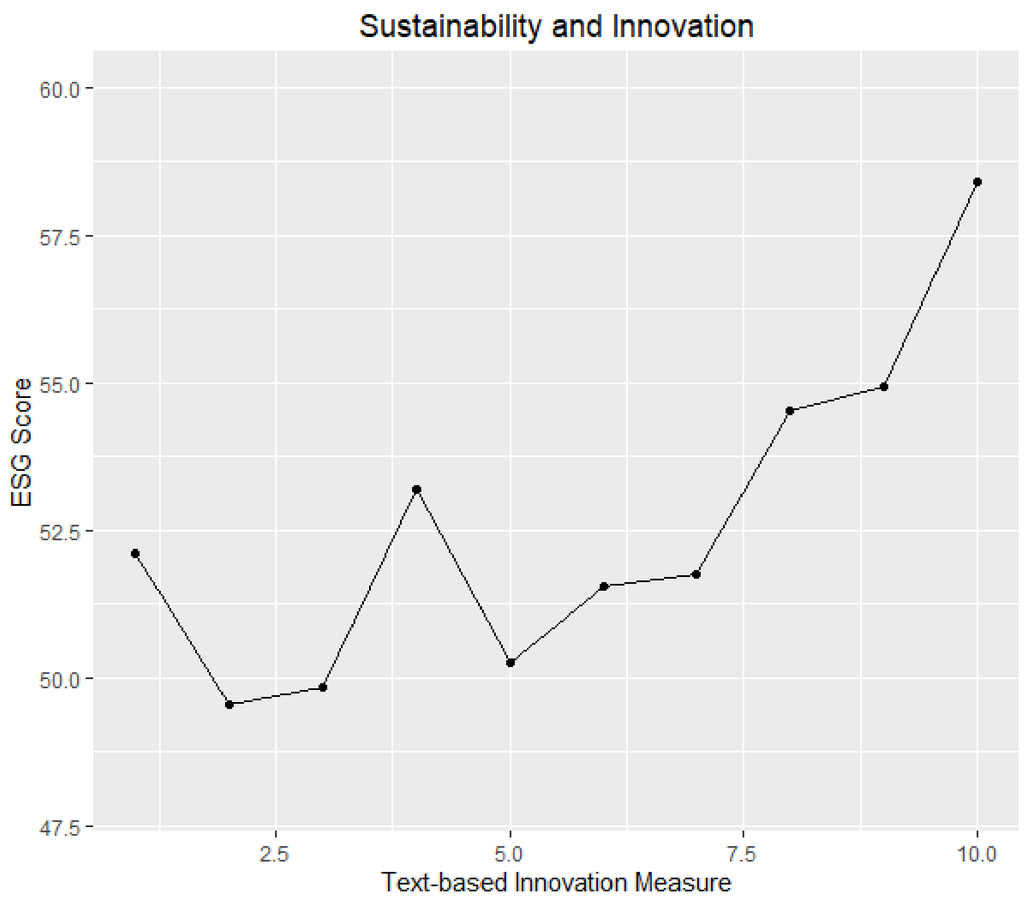
Accordingly, **sustainability and innovation are strongly connected**. This view is also shared by the United Nations, who see Science, Technology, and Innovation as key components of the Sustainable Development Goals of the 2030 Agenda for Sustainable Development (Walsh et al., 2020).

This led us to question whether companies who excel at innovation also lead other companies in the field of sustainability. So, **we examined how well innovative companies perform on their ESG measures** with a time-delay of one year.

To measure innovation, we used an approach from Bellstam et al. (2020). They developed a topic modelling method **to quantify a company's innovation capability from financial analyst reports** by calculating the frequency of innovation-related sentiments. The chart on the right shows the comparison of 939 companies, divided into 10 groups based on their text-based innovation measure and compared to their average ESG Scores.

The chart shows a **clear tendency that companies in the groups with higher innovation measures also have higher ESG Scores on average**.

In summary, our results show a significant positive correlation between **a company's perceived innovation capability and their ESG-Scores a year later.** We will now further investigate this relationship in different industries and countries.



Sources:

Bellstam, Gustaf; Bhagat, Sanjai; Cookson, J. Anthony (2020): A Text-Based Analysis of Corporate Innovation. In*: Management Science*. DOI: 10.1287/mnsc.2020.3682.

Walsh, P. P.; Murphy, E.; Horan, D. (2020): The role of science, technology and innovation in the UN 2030 agenda. In: *Technological Forecasting and Social Change* 154, S. 119957. DOI: 10.1016/j.techfore.2020.119957.

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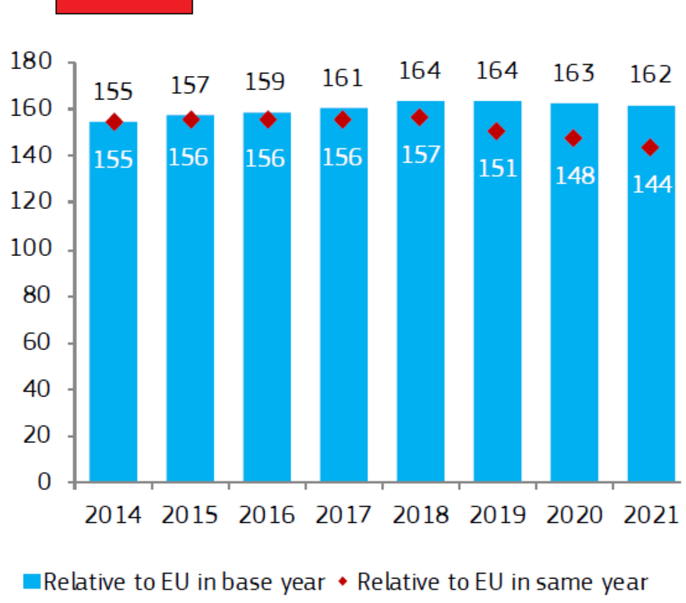
Innovation Efficiency and the Alpine Rhine Valley

Are companies from the Alpine Rhine Valley different?

Alpine Rhine Valley & Innovation

The Alpine Rhine Valley is frequently promoted as **one of the most dynamic and innovative regions** in Europe. The cross-boarder region is characterized through export strength, promotion of apprenticeship training, high industrialization and "secret world leaders" (Scherer et al., 2021). Filser and Eggers (2014) have shown that in the region, innovativeness has a significant positive effect on firm performance. Further, the Eastern Part of Switzerland takes the 6th place when it comes to interregional (European) comparison of innovativeness – measured by the European Innovation Scoreboard (EIS) (Scherer et al., 2021). However, despite being "on top"; the EIS shows that the innovativeness of Switzerland relative to other countries decreases continuously.

Switzerland is an **Innovation Leader**.
Over time, performance relative to the EU has decreased.

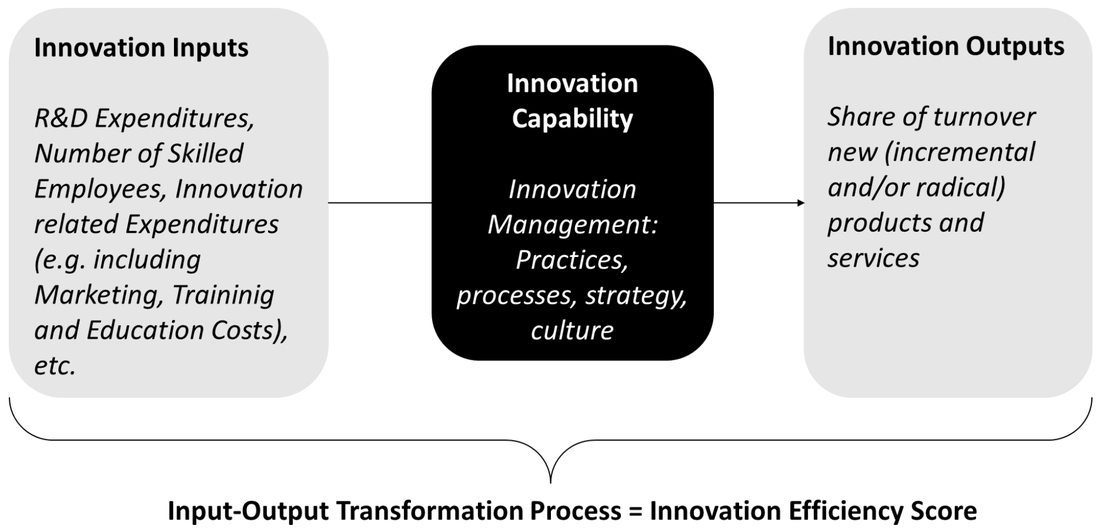


- How "innovation-efficient" are the Alpine Rhine Valley Companies?
- What are patterns of innovation-efficient firms?
- How can "we" become innovation efficient, respectively maintain innovation-efficiency?

Innovation Efficiency

Innovation efficiency is **considered a way of quantifying a firm's innovation capability**. It captures the transformational efficiency of realizing desired innovation outputs with a limited set of innovation resources (Cruz-Cázares et al., 2013; Song et al., 2015).

> *A firm's innovation capability is a multi-faceted construct that encompasses various activities, competencies, resources, culture, management practices, and organizational elements to create innovations. Competencies can be technology- or process- and skill based. These capabilities can be strengthened both internally and externally through acquisitions, networking, collaboration, and other actions.* (Bayrle et al., 2019, p. 14)



Within a dataset of 109 Swiss industrial companies, amongst them i.e., 6 of the LIHK Board, we find that companies in the Alpine Rhine Valley do not have a special advantage considering innovation efficiency. However, we do observe a distinction between **explorative and exploitative innovation efficiency**.

Patterns of Innovation Efficient Firms

Currently two research streams are followed: On one side, qualitative insights on Alpine Rhine Valley companies with different explorative and exploitative are gathered to gain deeper insights into **when which type of innovation efficiency** needs to be strengthened and deployed. On the other side, qualitative interviews with European companies are driven to find **about patterns of innovation-efficient firms** – and if they differ based on the geographical location. On the right, first tendencies are listed.

- Long term orientation and very open communication
- Quick decisions due to low hierarchy or responsibility to employees
- Distinctive error culture
- „Medium defined processes" and training employees in „entrepreneurial thinking"
- Fuzzy-Frontend: Hypothesis Testing

Sources: Bayrle, N., Stein, F., & Brecht, L. (2019). The Scope of Innovation Measurement/Capability/Performance: A Bibliometric Perspective. *ISPIM.;* Cruz-Cázares, C., Bayona-Sáez, C., & García-Marco, T. (2013). You can't manage right what you can't measure well: Technological innovation efficiency. *Research Policy.;* Filser M., & Eggers, F. (2014). Entrepreneurial orientation and firm performance: A comparative study of Austria, Liechtenstein and Switzerland. *South African Journal of Business Management;* Scherer, R., Zwicker-Schwarm, D., Moser, P., Haxhimusa, A., & Derungs, C. (Juni 2021). Die Ostschweiz und ihre Nachbarn - wie Corona die gernzüberschreitenden Verflechtungen beeinflusst. *IMP-HSG, ZWF, Zentrum für Verwaltungsmanagement.*

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Innovation and Inflation

Do innovation and technology lead to deflation effects?

Innovation & Technology

"An **innovation** is a **new** or **improved product** or **process** (or a combination thereof) that **differs significantly** from the **unit's previous products** or **processes** and that has been **made available to potential users (product)** or brought into use by the unit (process)." – OECD/Eurostat 2018

"Technology encompasses the current set of production techniques **used to design, make, package, and deliver goods and services in the economy**. So, technology is the application of selected parts of the knowledge stock to production activity." – Greenhalgh & Rogers 2010

Inflation

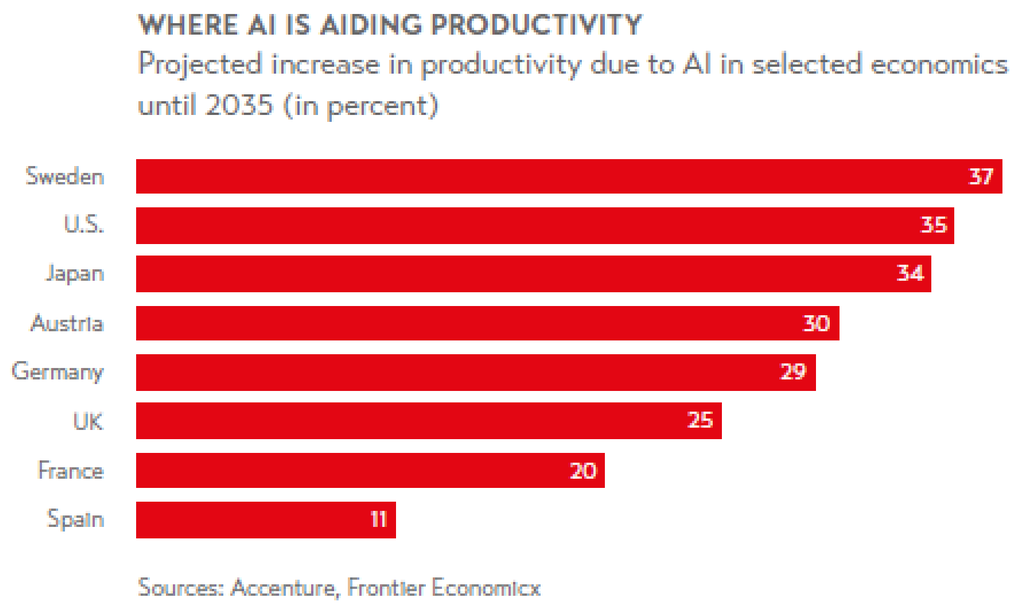
"The rate at which the general level of prices rise is called **inflation.** High rates of inflation often are associated with "overheated" economies, that is, economies where the demand for goods and services is outstripping productive capacity, which leads to upward pressure on prices. Most governments walk a fine line in their **economic policies**. They hope to **stimulate** their **economies** enough to **maintain nearly full employment**, but **not so much** as to **bring on inflationary pressures**. The **perceived trade-off** between **inflation** and **unemployment** is at the **heart of many macroeconomic policy disputes**." – Bodie et al. 2011

Innovation, Growth and Inflation

In recent years, **technological change** and **innovations** have **driven growth** and **productivity** across multiple channels (Trainer, 2016):

- **Machines** have **automated many low-skill tasks**, allowing workers to focus on areas where human intelligence and creativity can add more value.
- **Improvements in communications technology** have led to faster transmission of ideas and reduced many of the frictions that hindered productivity growth and innovation.
- Technology is constantly improving to be **more energy-efficient and use fewer raw materials**.
- The advent of **Big Data** has led to insights into how to **improve processes** and **eliminate inefficiencies**.
- The **Internet** has **removed** many of the **traditional market entry barriers** that protect companies from competition and has triggered a price race to the bottom in a number of categories.

Like other general-purpose technologies (e.g., the Internet), **AI (Artificial Intelligence**) has the potential to be an **important driver** of **productivity**. **Increased productivity per worker** is important to **offset the share of the labor force that is shrinking**:



Technology and **innovation affect inflation** by **generating productivity** improvements through **labor substitution**, e.g., through automation and networking. The **increase in aggregate demand** is **suppressed by artificial substitution**, which can lead to deflationary effects.

Sources: OECD/Eurostat (2018): Oslo Manual 2018. Guidelines for Collecting, Reporting and Using Data on Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition. The Measurement of Scientific, Technological and Innovation Activities. Paris/Eurostat, Luxembourg: OECD Publishing. Greenhalgh, Christine; Rogers, Mark (2010): Innovation, intellectual property and economic growth. Princeton, N.J: Princeton University. Bodie, Zvi; Kane, Alex; Marcus, Alan J. (2011): Investments and portfolio management. 9. ed., global ed. New York, NY: McGraw-Hill/Irwin. Trainer, David (2016): How The Internet Economy Killed Inflation. In: Forbes, 28.09.2016

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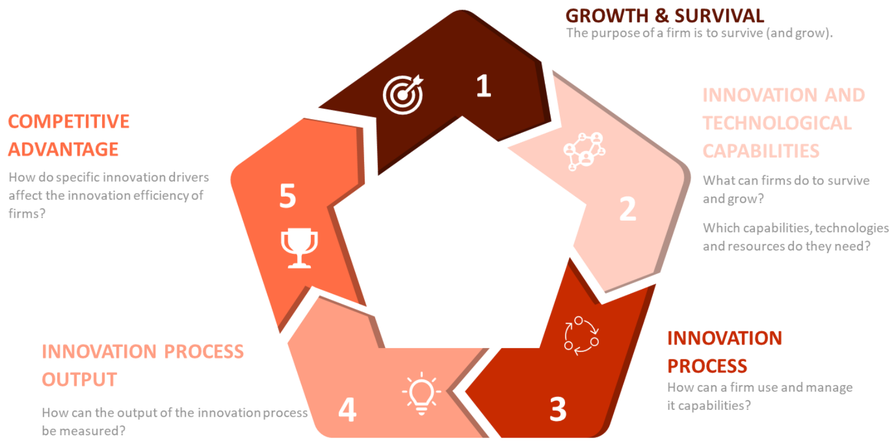
Innovation Efficiency and Firm Performance

Do innovation-efficient firms have a higher performance?

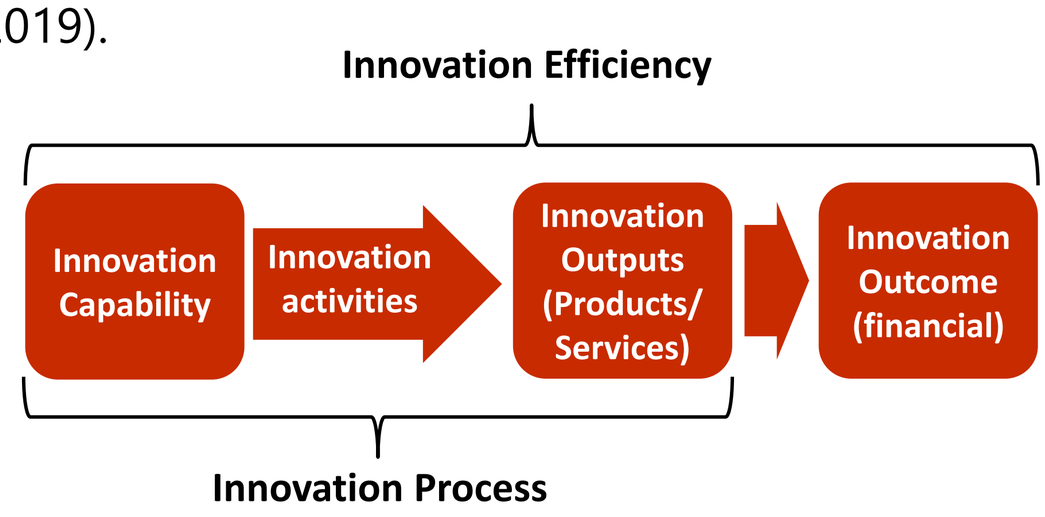
Innovation Capabilities and Innovation Efficiency

At the firm level, **innovation** is seen as an input to **achieve a competitive advantage** (Schubert and Simar, 2011; Zhang et al., 2014). Technologies are changing rapidly, product life cycle times are reduced, and competition is increasing (Lee et al., 2019; Park, 2018). Therefore, **innovation** is a **critical factor for firms to survive** in the modern business world (Lee et al., 2019).



Investments in innovation activities are usually **limited** by **financial** and **resource constraints** (Hottenrott and Peters, 2012, p. 1126). A firm's resource situation constitutes a widely used basis for explaining a firm's competitiveness and financial strength (Kauffeldt, 2014, p. 13). The idea of looking at firms as a set of resource bundles goes back to the work of Penrose (1959). The **Resource-Based View**, which builds on this idea, explains companies' **competitive advantage firstly by their specific advantageous resource situation** and **secondly by their more efficient use of resources** (Wernerfelt, 1984).

„**Innovation capability** allows companies to adapt rapidly changing markets and customers expectation in achieving innovation-driven growth". Yang et al. (2015). „A firm's innovation capability is a multi-faceted construct that encompasses various activities, competencies, resources, culture, management practices, and organizational elements to create innovations. Competencies can be technology- or process- and skill-based. These capabilities can be strengthened both internally and externally through acquisitions, networking, collaboration, and other actions" Bayrle et al. (2019).

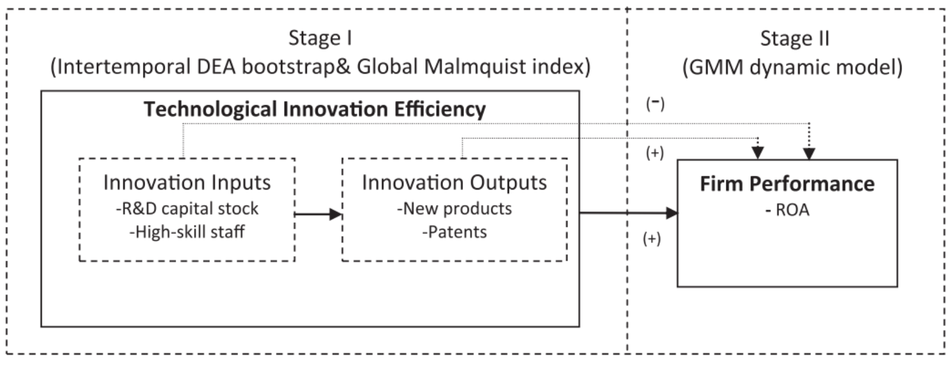


The innovation capability of firms is often determined based on input and output indicators of the innovation process in the form of an **innovation efficiency** measure (Tong and Liping 2009; Guan and Chen 2012; Wakasugi and Koyata 1997; Gao and Chou 2015; Hirshleifer et al. 2013; Almeida et al. 2013).

Innovation Efficiency and Firm Performance

There are several studies that examine the relationship between innovation efficiency and firm performance. Two core results are presented here as examples.

- **Empirical analyses on German Firms showed that product innovators (introducing a new product/service in the last three years) grew significantly more than non-product innovators.**
- **In the next step product innovators were selected, and it was shown that those product innovators who were efficient in their innovation process grew even more than the non-innovation efficient ones. Bayrle (2021)**



- **Cruz-Cázares et al. (2013) showed that in a dataset of Spanish firms, those with high innovation efficiency also had higher firm performance (here: return on assets).**

Sources: Schubert, Torben; Simar, Léopold (2011): Innovation and export activities in the German mechanical engineering sector: an application of testing restrictions in production analysis. In: J Prod Anal 36 (1), S. 55–69. Kauffeldt, Julian V. (2014): Quantitative Evaluation der Innovationseffizienz von Unternehmen. Dissertation. Ulm University, Ulm. ITOP. Bayrle, Niklas; Stein, Fabian; Brecht, Leo (2019): The Scope of Innovation Measurement/Capability/Performance: A Bibliometric Perspective. In: The ISPIM Innovation Conference – Celebrating Innovation: 500 Years Since daVinci. ISPIM Conference Proceedings. Florence: The International Society for Professional Innovation Management (ISPIM). Cruz-Cázares, Claudio; Bayona-Sáez, Cristina; García-Marco, Teresa (2013): You can't manage right what you can't measure well. Technological innovation efficiency. In: Research Policy 42 (6-7), S. 1239–1250. Bayrle, Niklas (2021): Innovation efficiency and firm growth: Methodological and empirical findings on firms. Dissertation. Universität Ulm.

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Innovation as a Factor

Does innovation explain stock market returns?

Innovation & Economic Growth

Innovation is one of the **most important factors** in the **growth of new products**, sustaining incumbents, creating new markets, transforming industries, and promoting the global competitiveness of nations.

Some authors claim to **invest more in R&D to increase the competitive edge and leadership**.

To strengthen their innovation capacity companies, invest in R&D and personnel, patents, and high tech/service exports. Hence, **innovation is mentioned as one of the main drivers for economic growth.**

The main research question is:

Does innovation explain stock market returns?

Modified Fama French

A **paper** from Gun Jea Yu, KiHoon Hong (2016) compares **two different models**, in order to investigate whether **corporate innovative activities**, represented by **exploitation and exploration**, could add explanatory power in **explaining stock price movements**.

- The first model is a combination of the **modified model of Chen and Zhang** (2007), **the Fama French three factor model and the previous period R&D expenditure**.
- Then the **second model** includes **exploitation** and **exploration** in explaining the excess stock return.

$$\text{Model1}: R_{it} = \alpha + \beta A_{it} + \gamma F_t + \delta RD_{it-1} + \varepsilon_{it}$$

$$\text{Model2}: R_{it} = \alpha + \beta A_{it} + \gamma F_t + \delta RD_{it-1} + \theta E_{it} + \varepsilon_{it}$$

whereby

- $\boldsymbol{E_{it}}$ is the number of exploitation / exploration for company i at time t and $\boldsymbol{RD_{it-1}}$ are research & development spends for company i at time t-1.

Modelling Results

- The **previous period R&D expenditure** and the **number of patents are statistically significant in explaining stock price movements (SPM).**
- The **coefficient of exploitation is positive and that of exploration is negative**. Activities aimed for **short-term performance** (exploitation) is **preferred** to these for long-term performance (exploration) by investors.
- The **magnitude of the estimated coefficients** for Accounting variables and Fama and French factors **do not change much when exploitation and exploration are included** in the analysis.
- This **indicates** that **none** of **these traditionally employed factors in explaining SPM can capture the impact of exploitation and exploration in explaining SPM**.

Estimation result: Model 2.

	Coeff	*p*-value	% R^2 contribution
x_{it}	−0.0151	0.00	3.19
$\Delta\hat{q}_{it}$	−0.0001	0.00	1.34
$\Delta\hat{b}_{it}$	−0.0102	0.00	3.01
$\Delta\hat{r}_{it}$	0.2393	0.00	3.62
SMB_t	−0.0114	0.00	5.37
HML_t	−0.0147	0.00	27.46
MKT_t	1.4513	0.00	41.63
RD_{it-1}	0.0075	0.00	2.45
EI_{it}	0.0012	0.00	3.33
ER_{it}	−0.0111	0.00	8.60
α	−0.1335	0.00	
R^2	0.0247		
N	14,324		

Yu, G. J. and Hong, K. (2016) 'Patents and R&D expenditure in explaining stock price movements', Finance Research Letters, vol. 19, pp. 197–203

Yu/Hong (2016) empirically find that the number of patents have more significant explanatory power in explaining SPM than R&D expenditure. Their results indicate that incorporating the number of patents in explaining SPM could add value for investors.

Sources: Yu, Gun Jea; Hong, KiHoon (2016): Patents and R&D expenditure in explaining stock price movements. In: Finance Research Letters 19, S. 197–203.

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Innovation and Robustness

How innovation-efficient firms invest in innovation?

Innovation & Efficiency

The **innovation efficiency of firms** can be investigated with the help of various methods and data sets. The starting point of this study is an innovation efficiency score based on Data Envelopment Analysis.

In general, it is interesting to determine which **characteristics innovation-efficient and non-innovation-efficient firms show regarding investment activities in innovations**. In addition, their characteristics in terms of firm performance and firm valuation are also of interest. The poster aims to identify the **investment patterns of innovation-efficient firms in contrast to non-innovation-efficient ones**. A period from 2007 to 2017 is considered to identify these characteristics. Innovation-efficient firms show superior performance in terms of valuation and financial indicators. Investing into innovation efficiency leads to a better future for firms: **Innovation efficient firms stay ahead of their competitors due to their steady investment into innovation activities**.

Eco-Up-and Down-Swings

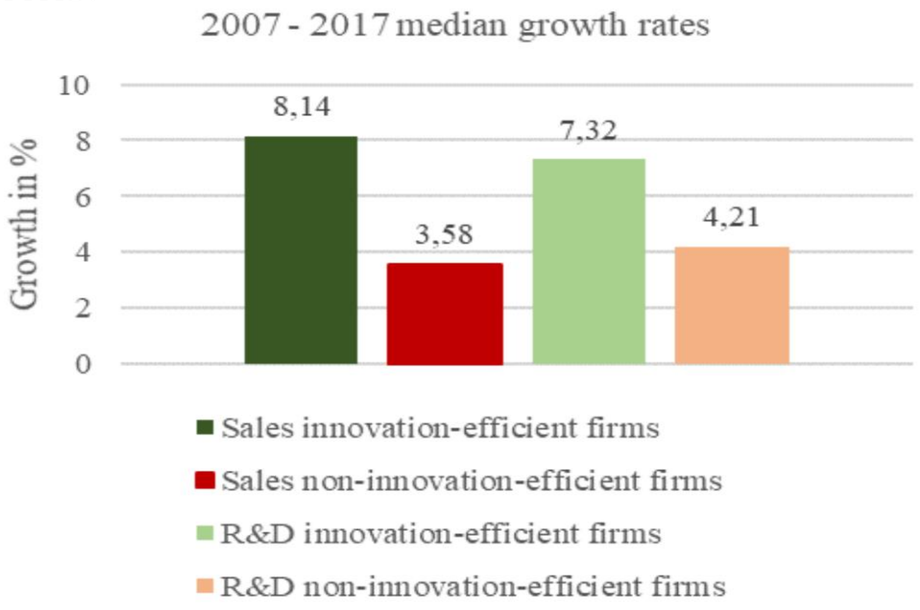
In order to **identify the investment patterns** of these firms, **variables to answer the research questions are needed**.

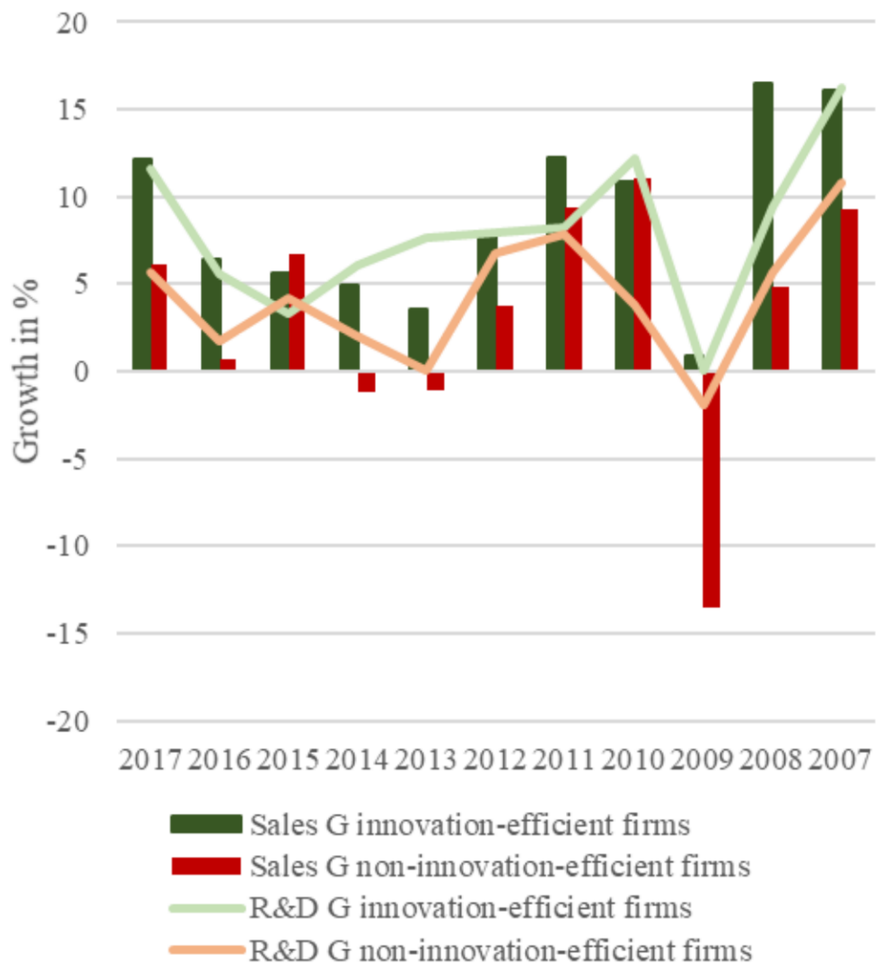
- The **first variable** is the **annual sales growth rate**, which is a good proxy for firm performance, although one has to consider possible limitations due to short-term growth drivers other than innovation.
- The **second variable** is the **annual R&D expenditures growth rate**, which is correlated with firm growth over a longer time horizon.

Innovation-efficient firms invested steadily into R&D expenditures growth and **increased** their R&D expenditures growth in comparison to their sales growth during an **economic slowdown**.
In contrast, **non-innovation-efficient firms invested more into R&D expenditures growth during economic upswings** (positive sales growth) and declined their rates during slowdowns (negative sales growth).

Quantification on Sales Growth and R&D Expenditures

- The **median of the innovation-efficient firms** in **terms of annual sales growth** was **8.14% versus 3.58% of non-efficient firms.**
- Looking at the **median annual R&D expenditure growth** there was a similar pattern, **7.32% for innovation-efficient firms versus 4.21% for non-innovation-efficient firms**.





In times of **economic slowdowns**, innovation-efficient firms kept **investing into R&D expenditures**. **Non-innovation efficient firms cannot keep up with this pace set by the top performers**.

Sources: Brecht, Leo; Bayrle, Niklas (2018): Investment Patterns of Innovation-Efficient Firms. In: International Journal of Trend in Research and Development (Hg.): International Conference on Trends & Innovations in Management. ICTIMESH-18. Dubai, December, 2018. Online verfügbar unter http://www.ijtrd.com/ViewFullText.aspx?Id=19219.

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