A controversial investment

An industrial policy analysis of the Intel-Magdeburg subsidy based on the BESTInvest guidelines

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Executive Summary

The US semiconductor company Intel is planning to build two ultra-modern chip factories near Magdeburg. This project was promised the largest industrial policy subsidy that the German government has ever approved for an individual company: almost 10 billion euros. Is this money well-spent? To answer this question, we developed guidelines for the evaluation of government investments (BESTInvest). This paper sets out these guidelines and applies them to Intel-Magdeburg. Our conclusion is that the subsidy is controversial. Although learning curve-, cluster- and innovation effects can create path dependencies in semiconductor production, there are uncertainties surrounding the size of these effects, and the impact of a single subsidy is likely to be moderate. Accordingly, it remains unclear whether the support would suffice to make Intel-Magdeburg competitive in the long term. In addition, relatively few jobs would be created, in a local labour market where there is currently a shortage of skilled workers. This calls into question the effects of the project on the regional and wider economy. In addition to economic factors, there are also relevant climate and sovereignty factors, which are positive but moderate. The overall assessment therefore depends on the respective weights given to individual factors, as well as, if necessary, on the willingness to promote cluster formation and the competitiveness of the semiconductor industry in Germany and Magdeburg with further measures.

#INTEL-MAGDEBURG
#SEMICONDUCTORS
#INDUSTRIALPOLICY

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Introduction

The establishment of an Intel site near the city of Magdeburg was expected to be one of the largest industrial policy projects in German industrial history. Intel wants to produce the world's most technically advanced chips with a structural size of 1.5 nanometres in the two planned factories. The German state planned to subsidise the 33 billion euro project with a subsidy of 9.9 billion euros (Die Bundesregierung 2023).

The project is now delayed by at least two years. It remains unclear whether it will go ahead at all. Nevertheless, the originally intended level of state support begged the question: Is it worth it?

The German government listed four goals that it aimed to achieve with the subsidy to Intel-Magdeburg: strengthening European sovereignty, promoting resilient supply chains, increasing innovation in German industry, and improving the labour market in eastern Germany. In addition, the government expected the German economy to benefit more generally from the catalytic effects of the investment (Die Bundesregierung 2023). The government also emphasised that it expects to see economic gains from this investment – for example, through more growth, higher tax revenues and lower unemployment (Bernardt et al. 2024).

Among economists, however, the subsidy was always controversial. While the VDI/VDE Innovation + Technik GmbH (VDI/VDE-IT) study "Economic effects of the Intel settlement in Magdeburg" comes to an overall positive conclusion regarding the economic viability of the project, other economists criticised the overall precarity of the project and the one-sided state intervention in the free market (Tagesschau 2023; Bernardt et al. 2024). In an interview, Clemens Fuest, President of the ifo Institute, also criticised that the Intel plant would only make a minor contribution to research and development in Germany due to its focus on physical chip production, and that public subsidies for increasing the resilience of supply chains could crowd out private sector efforts (Tagesschau 2024).

The economically volatile situation of Intel – which recently announced 15,000 job cuts – raises further questions. For one, there is criticism that with Intel, the state is subsidising a company that missed important recent waves of innovation and technical development. For another, it is unclear whether the initial subsidy will suffice or whether further government support will be required to keep Intel-Magdeburg competitive as a leading-edge location in Germany in the long term (Rudzio 2024).[1]

So: is the subsidy worth it? To answer this question, to deepen our understanding of industrial policy mechanisms, and to support future subsidy and investment decisions, we have developed guidelines for the evaluation of government investments (***Be****wertung von* ***st****aatlichen* ***Invest****itionen* – BESTInvest). In this paper, we set out these guidelines and apply them to the Intel case.

Section 1 provides an overview of the BESTInvest guidelines. Section 2 describes the Intel-Magdeburg project, while sections 3 to 5 apply the guidelines to Intel-Magdeburg and examine the economic, climate and sovereignty aspects of this project. Section 6 concludes.

[1] According to estimates by VDI/VDE-IT, further substantial investment would be necessary after about ten years to bring the plant up to the future leading-edge standard. Otherwise, the plant could slip into the common-edge segment, where significantly lower margins are achieved.

Our overall assessment is that, although the subsidy could increase Intel's competitiveness in the long term through various mechanisms, it will probably not be able to fully compensate for the plant's locational disadvantage in Germany. Concerning climate and sovereignty aspects, a positive but only moderate contribution can be expected.

Our analysis thus underlines that the Intel subsidy is controversial. Whether the money is judged to be well-invested depends on the relative weighting of (regional) economic effects, climate effects and the perceived probability of different geopolitical scenarios. This is a political judgement call, which we refrain from making.

1. BESTInvest: an evaluation guide for government investments

Smart industrial policy pursues specific goals. Historically, the promotion of *regional* and *economy-wide* prosperity have been key aims. Today, the *fight against climate change* and a *strengthening of European sovereignty* are further priority objectives. These are the four goals that the BESTInvest guidelines and their application to Intel-Magdeburg in this paper focus on.

To evaluate a particular investment or subsidy decision, it is helpful to assess the extent to which it is suitable for achieving these four objectives. The BESTInvest guidelines identify eight mechanisms through which a subsidy can plausibly achieve or support the objectives mentioned (see Box 1 for a description of the "learning curve effects" mechanism, and Table 1 for an overview of all eight mechanisms). On this basis, it describes various qualitative analyses and quantitative models that can be used to investigate the extent to which these mechanisms are effective in a particular project. As the mechanisms refer to economic and business processes, the BESTInvest guidelines can be applied flexibly to various investment projects.

Box 1: Learning curves as an example of our investigated mechanisms

Learning curve effects are an example of the kind of mechanisms we consider. Thanks to many years of practical experience in production, established companies have a cost advantage, and therefore often a competitive advantage, over newcomers. This can give established firms market power, which creates path dependencies and multiple equilibria. These in turn open the possibility of shaping the future economic structure through smart policies: For example, an industrial policy investment can contribute to making an initially subsidised company competitive in the long term through learning curve effects, thereby increasing local value creation.

The BESTInvest guidelines contain a brief literature review on how learning curve effects can reduce production costs through high production volumes. This process can be modelled differently depending on the industry and available data. We offer various suggestions to allow for a case-specific analysis, as well as an Excel tool that analyses learning curve effects in the semiconductor industry as an illustration.

Regarding **overall economic prosperity**, industrial policy action can be an effective instrument, particularly due to path dependencies. Path dependency effects enable an established company or cluster of companies to deter new entrants. They describe self-reinforcing processes that can arise, for example, through cluster effects or learning curves (see Box 1). In such cases, state support can help to overcome entry barriers and permanently shift economic development from a less attractive to a better path.

Path dependencies also play a major role in the effects of industrial policy measures on **regional economic prosperity**. They create the potential to promote specific regions in a targeted and sustainable manner with one-off subsidies or other policy measures. This can prevent both emigration and the economic decline of such areas, which contributes to more sustainable regional development and can increase local political stability.

Regarding **climate effects,** externalities are the key mechanism in the BESTInvest guidelines. Externalities are effects in the production or consumption of goods or services whose positive or negative repercussions affect not just the relevant producers, owners or consumers, but also other stakeholders. Private markets achieve suboptimal results here which can be improved by state intervention. Climate change is the externality that is generally given the highest priority today.

The economic mechanism that makes industrial policy a potentially effective instrument for sovereignty aspects, is the existence of incomplete insurance markets. There are scenarios that either exhibit great uncertainty because the probability of their occurrence and the resulting consequences are difficult to estimate, or where the consequences are so serious that no private actor can take the corresponding real economic and/or financial precautions to minimise risk. Such scenarios cannot typically be insured privately and their occurrence is often collectively underestimated by the corresponding players. If a society does not wish to bear the relevant negative risks in uninsured form, the state must act as insurer. One form of real economic protection can be industrial policy subsidies.

Table 1 describes the eight mechanisms along which the guidelines and analysis are structured. For each mechanism, the BESTInvest guidelines provide a description of how it works and an explanation of the extent to which it may justify state intervention. The guidelines then discuss options for analysis based on the current state of research.

To standardise and accelerate the analytical process, we have developed various quantitative tools for the respective mechanisms. This structure makes it possible to examine industrial policy projects quickly and in a standardised manner.

As the guidelines always focus on understanding the underlying mechanisms, they offer flexibility to adapt the analyses to individual needs and to the project specific context. Additional qualitative studies, such as literature research and expert interviews, can also be added. The guidelines therefore offer sufficient flexibility to cover even complex subsidy projects such as Intel-Magdeburg.

Dimension	Mechanism	Content	Potential market failure
Whole economy	Learning curve effects	• Cheaper production of established firms through learning effects • Quantitative analysis of sector-specific effects, depending on data availability • Supplemented with qualitative analysis	Path dependencies, externalities, market power
	Cluster effects	• Long-term cost and competitive advantages through cluster creation and suppliers- and client-networks • Qualitative analysis of sector-specific, competition-based cluster potential	Path dependencies, externalities, market power
	Innovation effects	• Path dependencies and positive externalities in innovation development, including innovation benefits through clustering • Quantitative analysis of R&D expenditures • Qualitative analysis of sector-specific innovation environment	Externalities, uncertainty and risk aversion
Whole economy & regional economy	Supply chain pull effects	• Support for the wider economy, especially along the supply chain, through investment • Quantitative analysis using an input-output model that depicts these linkages • Qualitative analysis to take account of specific features of the supply chain	Path dependencies, Keynesian underutilisation, externalities
	Private vs. public returns	• Cheaper capital costs for the state relative to the private sector; however, the capital returns to subsidised projects are often lower • Analysis of specific capital costs and potential returns of the investment project	Information asymmetries, uncertainty and risk aversion
	Labour market effects	• A liquid labour market as a pull factor for skilled workers and private investment as well as bolstering political stability • Efficiency analysis of job creation • Analysis of a potential skilled worker shortage using our labour market model	Externalities, political stability, coordination effects
Climate change	Countering externalities	• Effectiveness analysis based on net climate effects of the investment • Efficiency analysis that compares net climate effects relative to the investment sum	Externalities
Sovereignty	Incomplete insurance markets	• Scenario analysis to examine possible use-cases • Makes potential developments and their consequences more tangible	Uncertainty and risk aversion, political sovereignty aspects

Table 1: Overview of BESTInvest mechanisms; **source**: own analysis

2. The context: Intel-Magdeburg and the semiconductor supply chain

The Intel site near Magdeburg is set to become one of the largest industrial policy projects in German industrial history. The planned total investment of 33 billion euros is expected to be supported with a subsidy of 9.9 billion euros from the German government (Die Bundesregierung 2023). This makes the project the largest investment by a foreign company in Germany and at the same time the largest industrial policy support for an individual company by the German government (Bernardt et al. 2024).

The plant will produce semiconductors with a structural size of 1.5 nanometres. Upon completion, this would make Intel-Magdeburg possibly the first global production site for sub-2-nanometre semiconductors and thus the so-called "leading-edge" segment (Die Zeit 2024). The site comprises two semiconductor factories on an area of 450 hectares and is expected to create 3,000 jobs at Intel alone (Intel 2022).

The plant can be placed in the middle of the three-part semiconductor supply chain. As a front-end production facility, it is responsible for the physical manufacturing process of the electronic circuits. This places it between chip design, upstream in the supply chain, and back-end production, which lies downstream (Hess 2024).

Front-end production is currently a geographic bottleneck in the global supply chain. The Taiwanese company Taiwan Semiconductor Manufacturing Company (TSMC) holds a market share of 62 percent in semiconductor front-end production, with the majority of production taking place in Taiwan (Zandt 2024). TSMC's market share is even greater in semiconductors with a small structure size.

Driven by supply bottlenecks during the COVID-19 pandemic and increasing geopolitical tensions, various attempts have been made to diversify this front-end production. One example of this are the current investment efforts of Intel, which is entering the foundry business, i.e. the contract manufacturing of chips.

The European Union (EU) has also developed a plan with the EU Chips Act to protect itself from potential future supply bottlenecks. The EU Chips Act aims to achieve a 20 percent front-end production share of the global market in Europe. Among other things, it allows exceptions to European state aid law, which otherwise prohibits individual state subsidies.[2] As part of the EU Chips Act, for example, the German government is supporting the 10-billion-euro plant of the European Semiconductor Manufacturing Company (ESMC) near Dresden with a 5 billion euro subsidy.[3] Government support for the Intel plant can also be seen as part of the implementation of the Chips Act (Tagesschau 2023).

As described in the introduction, the almost 10-billion-euro subsidy for Intel-Magdeburg is controversial. We therefore apply BESTInvest to it and perform a structured analysis.

3. Economic analysis

A first important aspect in the assessment of the public subsidy for Intel-Magdeburg is the expected competitiveness and profitability of the plant, which determine its long-term effects on **overall economic** and **regional** prosperity. This determines whether the plant can produce in the long term with the help of the start-up investment, without having to rely on further state aid. If this is the case, the initial state support can lead to a sustainable economic boost in Germany and in the Magdeburg region, serve as a pull factor for other companies in the semiconductor industry, generate increased tax revenue and more jobs, and thus pay for itself in the long term.

[2] See Article 107 of the Treaty on the Functioning of the European Union.

[3] ESMC is a joint venture between TSMC, Bosch, Infineon and NXP Semiconductors. The Dresden plant, construction of which began on August 20, 2024, will produce semiconductors of medium technology standards that are in high demand in the automotive industry, for example (sachsen.de 2024).

The market structure of the semiconductor industry ensures that significant path dependency effects are possible. Intel plans to produce leading-edge chips with a structure size of 1.5 nanometres in Magdeburg, supposedly making it the first company in the world to enter the sub-2-nanometre segment. If they achieve this, it will initially give Intel a monopoly position allowing it to set prices more freely. Samsung and TSMC are also planning to produce leading-edge semiconductors before 2030, which would develop the market into an oligopoly (Böckmann 2024; Yu 2024). In this oligopoly, Intel should continue to have sufficient market power to compensate for certain locational disadvantages.

Nevertheless, the Magdeburg plant will have to compete with other producers. We therefore begin our economic analysis with an overview of locational disadvantages and advantages in Germany and Magdeburg, before going on to examine the six mechanisms used by the BESTInvest guidelines to classify the effects of an investment on overall and regional economic prosperity.

3.1 Advantages and disadvantages of Germany as a location for semiconductor production

Germany currently has several relevant locational disadvantages in terms of semiconductor front-end production. These include, for example, high energy and labour costs compared to other potential locations. According to a BCG study (2020), semiconductor production costs in the USA are around 50 percent higher than in China and 30 percent higher than in Taiwan. The main reasons for this are high labour and energy costs as well as lower government subsidies. Due to even higher energy costs, the locational disadvantage in Germany is likely even greater (ZfK 2023).

In addition, the relevance of locational aspects is currently shifting. The increasing automation of production processes means that labour costs are becoming less important (Tembey et al. 2023). Energy costs, on the other hand, become more relevant as the technical development of chips progresses, as energy costs continue to rise as the chip size decreases (imec 2023). As both labour costs and energy costs are comparatively high in Germany, it is expected that the fundamental locational disadvantage will persist.

However, there are also some aspects that could strengthen Germany's competitive position in the long run. Germany is regarded as a secure production location in terms of both safeguarding supply and preventing manipulation of the chips, e.g. to eavesdrop on end-user activity. In addition, the German energy mix is significantly more sustainable than that of Taiwan or China (Arnhold 2024; Fabian 2024; see also section 4 below). In a Bitkom study, 83 percent of the 358 German companies surveyed stated that the semiconductor manufacturing country was important to them (Bitkom 2023). However, economic factors play an even more important role: 93 percent describe the price-performance ratio as "extremely important". 80 percent say the same about short delivery times and 69 percent about adherence to delivery quantities. However, this could change as geopolitical tensions escalate and economic internalisation of climate aspects increases, thus offering potential for the future.

The question therefore arises whether the Intel site will be economically viable in the long term and whether the state investment will pay for itself. The VDI/VDE-IT study "Ökonomische Effekte der Intel-Ansiedlung in Magdeburg" estimates that Intel will generate an annual turnover of 2.6 to 10 billion euros during the first ten years in Magdeburg, and thus up to more than one sixth of Intel's total turnover (presently 53.4 billion euros) (Bernardt et al. 2024; Statista 2024a). Hence, the public subsidy should pay for itself after around 30 years.

However, accurate forecasting over this time horizon is hardly possible. The calculation does not consider many second-round effects, such as those caused by pull effects on companies in the cluster. In addition, Intel would have to invest significantly again after around ten years to maintain the leading-edge status which enables the company to achieve high margins. It is unclear whether such investments are planned and whether the state will also have to support them. While paying for itself therefore seems possible in principle in the long term, it is associated with major uncertainties.

In the following, we analyse various economic effects that influence this uncertainty in more detail. We also investigate other positive effects of the Intel subsidy apart from potentially paying for itself. In doing so, we are guided by the overall economic and regional economic mechanisms described above. We investigate path dependencies by analysing learning curve and cluster effects. We also take a closer look at innovation effects, analyse catalytic effects through supply chain pull effects, and examine the differences in capital costs and returns between private and public investments. Finally, we look at the impact of the Intel plant on the labour market.

As they are closely interlinked, we predominantly treat overall economic and regional economic aspects together in the analysis of the relevant mechanisms. At the end of the chapter, we provide an overall economic and a regional economic summary to enable an assessment from both perspectives.

3.2 Learning curve effects

Learning curve effects describe the decrease in costs associated with increasing aggregated production volumes, for example, driven by the optimisation of production processes (Cunningham 1980). Learning curve effects can lead to path dependencies. Projects that were initially uneconomical can become competitive if costs fall accordingly. Thus, a state investment can make sense if potential locational disadvantages, such as higher energy or salary costs, are offset in the long term by learning curve effects with corresponding production volumes.

The specific learning curve effects of the Intel plant in Magdeburg are difficult to predict, as it is the world's first 1.5 nanometre semiconductor production facility. Accordingly, we have focused our analysis on the cost development of 5-nanometre chips, which are also high-end chips with similar production conditions. Based on expert interviews, we estimate a learning curve effect of 20 percent for 5-nanometre chips and similar chip types. This implies a cost reduction of 20 percent with a doubling of the aggregated production volume.

According to our estimate, Intel's learning curve effects should be roughly in line with the market average. Although Intel has experience in ramping up production processes and, as a global group, has the appropriate resources for this, the same also applies to other semiconductor manufacturers, in particular TSMC, which is considered to be particularly efficient in ramping up production processes. In addition, the Intel-Magdeburg plant is expected to achieve production volumes on a par with other high-end semiconductor production facilities. The question is therefore whether Intel will be able to compensate for Germany's locational disadvantage by being ahead of the ramp-up of 1.5-nanometre production planned for 2027 (Astheimer et al. 2023). TSMC will probably also produce sub-2-nanometre chips commercially beginning in 2028. Subsequently, we expect the learning curve effects of the Intel plant to run parallel to the market or slightly slower than at TSMC.

3.3 Cluster effects

Other path dependencies can arise through cluster effects, which represent positive synergies of established production networks along the supply chain. For example, delivery costs and times are reduced when suppliers and customers are located close to the semiconductor plant and well-established coordination mechanisms are in place.

Cluster effects were repeatedly cited as justification for the state investment in the Intel plant. The plant in Magdeburg, for example, is referred to as the "Silicon Junction" (Intel 2024). The VDI/VDE-IT report "Ökonomische Effekte der Intel-Ansiedlung in Magdeburg" also emphasises the potential of a cluster structure supported by the Intel plant (Bernardt et al. 2024).

However, some cluster effects in the semiconductor industry are less pronounced than in other industries. Due to the high value density of semiconductors, i.e. the high price in relation to weight and volume, delivery costs are less significant. The semiconductor supply chain is also extremely complex. According to Marc Bovenschulte from VDI/VDE-IT, a fully self-sufficient production cluster is inconceivable. In addition, requirements are often very specific, such that even if there is a similar company in the cluster, the more suitable company for the specific requirements outside the cluster is often chosen. In Germany, for example, there are various examples of companies that have opted for global procurement rather than local clusters. For instance, VW recently decided to source its automotive semiconductors from the Czech-based US company Onsemi instead of the German company Infineon (Hofer 2024). As of now there is no established semiconductor industry around the Intel plant in Magdeburg. Existing German clusters related to the semiconductor industry are located near Dresden and Munich instead.

Nevertheless, there are also some relevant cluster effects in the semiconductor industry, especially in the service sector. These allow the Intel plant to also benefit from the semiconductor cluster near Dresden. For example, specialised cleaning and maintenance companies are necessary for the operation of a semiconductor plant.[4] These benefit from being able to serve several semiconductor manufacturers at the same time. In addition, a 24-hour service is required to rectify technical problems, as it is crucial for the functionality of the production machines that they are in continuous operation. In addition, the timely delivery of intermediate goods is crucial to meet production schedules. Geographical proximity within a cluster minimises potential delivery risks in this respect.

3.4 Innovation

Due to positive externalities, support for innovation is an important goal of government investment. Due to cumulative effects in innovation and development, this is often path-dependent (Janeway 2018; Mazzucato 2018). An initially uneconomical path can develop into a profitable one in the long term through innovation if the state provides start-up financing that private players would not have been prepared to provide on their own.

A common approach to assessing the innovative capacity of a project is to analyse the research and development (R&D) expenditures (Peters et al. 2012). This allows for a quantitative analysis and thus a comparison with other projects. However, a qualitative analysis is often better suited to incorporating industry-specific factors and identifying possible quantum leaps in development. We therefore carry out both analyses below.

Intel does not provide any specific target figures for R&D expenditure or turnover at the Magdeburg site. Group-wide, R&D expenditure

[4] The clean rooms of a semiconductor plant must be far cleaner than e.g. a medical operating theatre. This can only be achieved by specialised cleaning companies (VDI/VDE, 2024b).

amounts to 30 percent of turnover (macrotrends 2024). According to the think tank *Interface*, however, the R&D share in a front-end production plant is significantly smaller than in chip design, for example.[5] It is likely that the proportion of R&D at the Intel plant in Magdeburg is somewhat lower, as the focus there is on the mass production of chips, while R&D activities are mainly carried out in the USA.

Based on these assumptions, we assume an R&D share of 7 percent for the Magdeburg site. Based on the turnover estimates of the VDI/VDE-IT, which range between 2.6 and 10 billion euros, this results in annual R&D expenditure of 182 to 700 million euros (Bernardt et al. 2024).

This estimate already includes a positive crowding-in effect of government funding, as the R&D expenditure was estimated based on the total turnover, although only one third of the project is to be funded by the government. Nevertheless, this is a conservative estimate, as further crowding-in effects may occur, for example through synergies from government funding or a favourable research environment in Germany (Fier et al. 2005).

In addition to direct R&D investments, further innovation effects can take place in the context of industry-specific cluster formation. In the semiconductor industry, however, such effects among competitors are less pronounced than in other industries, as technical innovations are generally kept secret and are difficult to copy. Nevertheless, there are also innovation-specific cluster effects in the semiconductor industry. For example, agreements with the customers of the chips offer certain advantages: Semiconductors that have been individually developed for their specific end-use are significantly more efficient.

In principle, part of this development must be carried out in close consultation with clients and on site, as production, for example, must also be tailored to specific needs. R&D with an operational focus is therefore typically also carried out at production plants. However, it is unclear to what extent such agreements benefit from the geographical proximity of a cluster, as they depend heavily on the specific requirements of the current technology of the clients. For example, Infineon from the east German semiconductor cluster was expected to supply VW. Instead, however, VW decided to source its semiconductors from the Czech branch of the US company Onsemi (Hofer 2024). Specific technical innovations among clients are also difficult to predict. At present, the automotive industry mainly uses semiconductors of medium technology standards. The German government hopes that Intel's leading-edge chips will also become relevant for the German automotive industry in the future and drive innovation, but the industry has not yet made any concrete plans in this regard.

In sum, the low R&D expenditure in relation to the investment sum alone hardly justifies the investment. This is also emphasised by Clemens Fuest, President of the ifo Institute (Tagesschau 2024). Instead, it is the cost- and production-related cluster synergies as well as potential production-related innovation processes that speak in favour of the Intel investment. However, these are associated with considerable uncertainties.

3.5 Supply chain pull effects

Supply chain pull effects are another key aspect in the economic analysis of the Intel plant. These refer to the extent to which other companies along the supply chain benefit from the investment. An investment not only increases

[5] TSMC, a company that focuses on front-end production, has an R&D share of less than 10 percent (Statista, 2024c).

production in the specific plant, but also the demand for upstream intermediary goods. These intermediary goods must in turn be produced, which also increases the demand for their own intermediary products. This creates supply chain pull effects that branch out into the entire economy. For example, investing in a semiconductor plant requires processed silicon, which in turn requires machines and energy to produce, and so on. This not only leads to an increase in gross domestic product, but also to new jobs and higher tax revenues. Supply chain pull effects are therefore an essential factor in the profitability analysis of the investment.

To analyse these effects, we used the DESTATIS input-output model, which divides the economy into 72 sectors and maps their interdependencies. This model is used by the Federal Statistical Office as part of the national accounts to analyse changes in demand, among other things (Destatis 2024). To examine the effect of the Intel investment, we have increased turnover in the "computer, electronic and optical products" sector, which also includes semiconductors (Destatis 2019). As a result, turnover in other sectors rose by 58 percent of the increase in the "computer, electronic and optical products" sector. This can be regarded as the lower limit of the supply chain pull effects of the Intel investment, as the input-output model does not depict any intra-sectoral effects. In addition, the effects were calculated under the assumption of constant "last use". This means that final demand only changes in the sector under investigation, while the other sectors merely adjust their production to the demand in the relevant sector. Dynamic effects such as price changes or shifts in demand that go beyond the mere fulfilment of increased demand can therefore not be taken into account. Nevertheless, the model provides a well-founded lower limit for supply chain pull effects and enables comparison with other industries. For example, the effects in the "motor vehicles and parts" (55 percent) and "electric power and electricity, heating and cooling services" (52 percent) sectors are slightly lower. However, many interdependencies in the economy run along similar main branches, which is why the effects in the various industries are relatively close to each other.

To calculate the overall economic effects of the Intel settlement, VDI/VDE-IT, in cooperation with its project partner, the Institute of Economic Structures Research (GWS), used the more complex INFORGE model, which overcomes some of the limitations of our model (Bernardt et al. 2024). This model enables a dynamic simulation that can map price and demand shifts. This allows the separate analysis of the construction and production phases of the Intel plant. Based on this model, gross domestic product would increase by 2.6 billion euros in both the construction and production phases. In the production phase, a gross value added of 1.5 billion euros is expected in Saxony-Anhalt, of which just under 1 billion euros is attributable to the "manufacture of computers, electronic and optical products" sector. In the rest of Germany, a net increase in gross value added of 2.8 billion euros is expected, spread across a wide range of sectors. This includes a cannibalisation effect and thus a decline of around 0.3 billion euros in the "manufacture of computers, electronic and optical products" sector.

Accordingly, the supply chain pull effects increase considerably through the modelling of economic dynamics. However, the INFORGE model is also based on a similar division of the economy into 62 sectors, which makes the simulation of intra-sectoral effects more difficult. In addition, the model is based on a large number of assumptions that can have a significant impact on the results. For example, the interconnectedness of the semiconductor supply chain often depends on individual decisions about where to source intermediates, which can be very different from the standard coefficients of the "manufacture of computer, electronic and optical products" sector. The model also concentrates on demand-side developments and only depicts supply-side changes, such as innovation, based on assumptions.

Based on the results discussed, it can be assumed that the overall economy will benefit from the investment well beyond the pure production of the Intel site. However, the extent to which the gross domestic product is improved depends on the economic situation and, in the longer term, on innovation development and cluster formation.

3.6 Private vs. public returns

In the economic analysis of an investment, it must be considered that both the cost of capital and the returns on capital for a state-supported investment may differ from those of a purely privately financed investment. State-supported investment projects typically have lower capital costs, but often also lower rates of return (Chen et al. 2011; Deng et al. 2020).

When analysing this mechanism, it is important to distinguish between economic and business considerations. Although the economic results are ultimately decisive from a government perspective, the business aspects influence Intel's competitiveness and are therefore also relevant.

If we, for the economic study of the Intel investment, assume a capital cost of 2.2 percent for the state's share of 10 billion euros[6], compared to 9.9 percent for the private investment share, the annual cost of capital is 770 million euros lower (Bloomberg Finance L.P. 2024; Deutsche Finanzagentur 2024). From an economic perspective, the rate of return with state support could therefore be 2.6 percentage points lower before the benefit of the lower capital costs would be cancelled out. If we considered a rate of return of 20 percent on the investment sum with purely private financing, the rate of return with state support could fall to 17.4 percent, i.e. a drop of 13 percent, before it would be worse off economically than purely private financing. However, German electricity prices were 78 percent higher than Taiwanese prices in September 2023 (GlobalPetrolPrices.com 2024). If the energy costs of a semiconductor plant were 25 percent, the operating costs of a German plant would be around 20 percent higher, which would significantly reduce the return on investment.

From a business perspective, i.e. for the analysis of competitiveness, the capital costs of the state financing share can be completely ignored, such that the rate of return is likely to be 3.3 percentage points lower compared to purely private financing. This gives Intel more leeway in semiconductor competition. However, it must be recalled that Intel's competitors usually also receive state support. Data on the returns of individual plants are not available, meaning that no direct comparison can be made in this respect.

3.7 Labour market effects

Labour market effects play a key role in the evaluation of government investments, as they can have regional and supra-regional effects on the economy and society. The supply of labour must also be taken into account, particularly with respect to a potential shortage of skilled workers.

Around 3,000 jobs are to be created at the Intel plant in Magdeburg, of which around 70 percent will be in the technical area. A university degree is required for about 900 of these positions (mdr 2023). The German government assumes that around 15,000 additional jobs will be created throughout the economy as a result

6 Based on the interest rate of 10-year German government bonds at the time of writing.

of the Intel facilities (Die Bundesregierung 2023). Böttcher et al. (2024) forecast 19,000 newly created jobs in a study examining the labour market effects of the Intel location. A study by the Semiconductor Industry Association (SIA) estimates an employment multiplier of 6.7 for the US semiconductor market, which would indicate a similar effect of around 20,100 additional jobs. The VDI/VDE-IT predicts that 4,500 jobs will be created within the semiconductor supply chain, in addition to Intel. During the construction phase of the plant, 7,000 jobs are also to be created in the construction industry (Intel 2022). In the production phase, the state subsidy of 10 billion euros will create a total of between 15,000 and 20,100 jobs, which corresponds to a rate of around 0.5 to 0.7 million euros per job created.

Despite the high costs per job created, filling these positions through the regional labour market represents a considerable challenge. According to data from the Federal Employment Agency, there are currently around 3,260 full-time employees in the mechatronics and automation technology occupational group in Saxony-Anhalt, 7,360 in electrical engineering and 1,930 in technical production planning. However, there is an acute shortage of skilled workers in these sectors throughout Germany, and particularly in Saxony-Anhalt. The ratio of registered vacancies to unemployed people in the mechatronics and automation technology occupational group is 2.8 across Germany and as high as 3.8 in Saxony-Anhalt. According to the Federal Employment Agency's scale, a value of 1 already indicates a considerable shortage of skilled workers. Böttcher et al. (2024) therefore assume that around 60 percent of the required skilled workers will have to be recruited from outside the region. However, this will not be easy, as there is a global shortage of skilled workers in the chip industry. Ondrej Burkacky from McKinsey estimated in an interview with Handelsblatt that there are currently around 300,000 vacancies in the chip industry in the USA. The shortage of skilled workers may be further exacerbated by the numerous investments made by the various semiconductor manufacturers. ESMC, Infineon and Wolfspeed, among others, are planning new semiconductor plants in Germany, and semiconductor manufacturers are also expanding their capacities globally (Hofer 2023).

However, Julia Bütow from the State Chancellery of Saxony-Anhalt also sees an opportunity for Germany in this global shortage of skilled workers. In an interview with Dezernat Zukunft, she emphasised the well-developed infrastructure and German training system as well as the legal certainty in Germany compared to other semiconductor production locations. This offers the potential to develop a workforce cluster, with the Intel name acting as an anchor. In addition, 40 study places were created in a new "Advanced Semiconductor and Nanotechnology" degree path at the University of Magdeburg (Frankfurter Rundschau 2023). Moreover, five universities are collaborating to create 100 undergraduate degree spots for AI engineers (Hofer 2023). Intel wants to support the universities in Saxony-Anhalt with around 1.2 million euros (Böttcher et al. 2024). Intel is also planning to train specialists itself, with a training partner providing support in the first two years. In the long term, skilled workers in the German chip industry could benefit from a sound education and would have a greater choice of employers in the sector. This could also promote innovation processes in the region and create a decisive locational advantage.

Overall, the investment could lead to a revival of the regional labour market and be seen as a signal of new beginnings. At 7.7 percent in August 2024, the unemployment rate in Saxony-Anhalt is significantly higher than the German average of 6.1 percent and roughly corresponds to the average for eastern Germany of 7.6 percent (Statista 2024b). However, the measure is not only cost-intensive, but it will also be challenging to fill all the jobs, especially with people who already live in the region. The sudden increase in demand for skilled workers could also exacerbate the labour market situation among competitors, which could imply further regional difficulties.

Conclusion for the overall economy

From an overall-economy perspective, the Intel project offers a lot of potential, but is also associated with significant uncertainty. Learning curve and cluster effects can strengthen Intel's competitiveness in the long term, but even if they develop positively, they are probably not enough to compensate sufficiently for the disadvantages of the location. The general research expenditure triggered by this project in the German economic and research landscape would be low. If cluster formation does take place, however, there may be innovation in production processes. Moreover, compared with automotive or energy supply investments, the expected supply chain pull effects of the plant are greater; however, the exact effects on the rest of the economy can only be roughly estimated based on existing input-output tables.

Conclusion for the regional economy

The uncertain extent of cluster formation also complicates regional economic evaluation. According to the "Zukunftsatlas 2023", the region around Magdeburg only ranks 69th out of 85 regions in Germany regarding its innovative strength (Haag et al. 2023). The VDI/VDE-IT study (2024) also deems it challenging to develop a high-tech cluster in the Magdeburg region. However, even the establishment of a comparatively small semiconductor cluster in Saxony-Anhalt could strengthen the economic activity of the structurally weak region, as illustrated by the significant supply chain pull effects related to the region. The Intel location would also stimulate the regional labour market, while at the same time increasing the considerable shortage of skilled workers in the relevant occupational groups locally.

4. Climate and environmental effects

Semiconductors affect climate through multiple channels, and assessing the climate impact of a specific semiconductor plant is complex. Chip production and the use of many end products are emission-intensive, but semiconductors are also essential components of future-oriented technologies such as systems for autonomous driving and artificial intelligence. According to Julia Bütow from the State Chancellery of Saxony-Anhalt, such technologies are expected to contribute to reducing emissions in the long term through increased efficiency and innovation. In our analysis, we therefore distinguish between the climate effects during the production process and those of the end use.

Chip production has a significant impact on the climate. With the Chips Act, the EU wants to increase its global market share to 20 percent of front-end production, which could at least quadruple emissions, and possibly even increase them eightfold. This would make the future emissions volume of the semiconductor industry comparable to the current emissions volume of the chemical or steel and iron industry.

Other environmental aspects include not only CO_2 emissions but also the enormous amount of water required, the risk of chemical contamination, and potential environmental damage during the extraction of raw materials. Along the supply chain, the Intel plant, with its focus on front-end processes, carries out the most emissions-intensive step (Hess 2024). In addition, the demand for energy, water and chemicals increases as the chip structure size decreases, which is why Intel's leading-edge site will be particularly energy-intensive (imec 2023).

Due to the potential environmental and climate damage caused by growing chip demand, experts emphasise the importance of low-emission production (Favino 2024). Intel has developed the RISE 2030 strategy, which aims to cover its entire electricity demand from renewable energies by 2030. However, Julia Hess from Interface points out that it would be better for the environment if renewable energy were sourced locally, whereas this is often done from cheaper countries such as Norway. Intel is also planning to prevent the groundwater level in the production regions from dropping, for example by creating tributaries (Intel 2024). Further measures, such as participation in reforestation projects in Saxony-Anhalt, are also planned. More detailed information on the pro-environmental measures of the Magdeburg site has not yet been published by Intel.

As semiconductors are indispensable for a variety of technologies, the question is not whether they are produced, but where and how. Scope 1 and Scope 2 emissions are particularly important here, accounting for around 80 percent of total emissions in front-end production (Burkacky et al. 2022). Based on imec data, which takes Scope 1 and 2 into account, the production of a 3-nanometre chip in Germany emits around 39 percent fewer kilograms of CO_2 equivalents per wafer than the global average (imec 2024). Compared to Taiwan, this would be about 53 percent less. This is mainly due to the higher share of renewable energies in the German electricity mix, which reached 54 percent in March 2024, while Taiwan is aiming for a share of 20 percent by 2025 (Arnhold 2024; Fabian 2024). However, the supplier network in Taiwan is more optimised, which is why the difference along the entire supply chain is likely to be smaller. Compared to alternative Western production locations, however, Germany has higher emissions in some cases according to the imec tool. Ireland would produce around 7 percent fewer emissions than Germany, and Oregon (USA) even 11 percent fewer emissions. The imec data is also based on model calculations. The actual emission values may vary depending on the type of chip. Exact data on the production emissions of the Intel plant are not currently available.

In addition to the production conditions, the climate effects of end use also play an important role. In principle, emissions in production do not necessarily correlate with those in end use. Hyperscale data centres, for example, cause significantly higher operating emissions than smartphones, although both use cutting-edge semiconductors. According to Julia Hess from Interface, semiconductors generally become more energy-efficient as the structure size decreases. Nevertheless, rebound effects should also be considered when assessing climate effects. Increased efficiency and the associated cost benefits often lead to higher consumption, which can cancel out some of the emission savings. Rebound effects are difficult to estimate due to the complexity and diversity of feedback mechanisms, and there is little reliable data. According to a literature study by Sorrell (2007), the average rebound effect is around 30 percent of the original emissions reduction.

Overall, it is to be expected that the Intel site in Magdeburg would produce in a more climate-friendly way than other global locations, especially Taiwan. Nevertheless, there will be a considerable climate and environmental impact, which will also be higher than in certain alternative locations such as Ireland or parts of the United States.

5. Sovereignty aspects

To investigate the Intel plant's impact on Germany's sovereignty, we have prepared a scenario analysis. As highlighted by Amer et al., (2013) new analytical insights can be gained through the narrative development of scenarios, especially when it is difficult to carry out a reliable quantitative analysis. For our analysis, we worked with Interface, a think tank focusing on technology and social issues, to examine three potential scenarios for the year 2035: a baseline scenario, a European semiconductor upswing scenario and a Taiwan supply chain disruption scenario. By 2035, we presupposed the Intel plant to be established, which will enable a sound analysis of its impact. In the baseline scenario, the semiconductor industry develops as we forecast. In the semiconductor upswing scenario, the European semiconductor market develops as strongly as possible given its current starting conditions. For example, innovations and trends in the industry fit well with the European production landscape to generate synergies and growth. In the Taiwan supply chain disruption scenario, the supply of semiconductors from China and Taiwan is largely cut off, for example due to a conflict between the two countries. We have analysed these three scenarios based on the three dimensions of industrial supply security, military sovereignty and competitiveness.

Some introductory information is relevant for the following analysis. Regarding security of supply, there are four main client sectors in Europe: automotive, heavy industry (especially robotics and Industry 4.0), telecommunications and medical devices. Leading-edge semiconductors are currently not required for these industries; instead, they are used in computing-intensive end devices, especially in AI applications. In addition to the Intel plant, the European Semiconductor Manufacturing Company (ESMC), a joint venture between TSMC, Bosch, Infineon and NXP, is also planning a new plant near Dresden with an investment value of more than 10 billion euros. This plant will mainly focus on logic chips of medium technology standards with a structure size of around 28 nanometres. These chip types are primarily required in the before-mentioned European client industries. Other significant semiconductor companies based in Europe are GlobalFoundries and Wolfspeed (although the latter has also run into problems recently). Nevertheless, the European supply, even with the new plants, only covers a small proportion of around 5 to 10 percent of European demand.

Regarding military supply, semiconductors are required for weapons systems and AI accelerators. Semiconductors for AI accelerators in the military are currently largely designed by the US company NVIDIA and manufactured in Taiwan by TSMC. Other relevant designers are AMD and Intel. In semiconductor manufacturing, only Intel is at a similar technical level to TSMC, although the company does not currently produce AI accelerators designed for the military. Some sovereignty could be gained, if Intel-Magdeburg effectively enters the production of such chips. However, the extent is unclear: contrary to heavy industry, which quickly comes to a standstill in the event of a supply disruption, supply disruptions in AI accelerators in the military do not restrict the immediate ability to act, but only the supply of relevant military equipment.

Semiconductors for weapons systems, such as anti-aircraft missiles, which have to be produced in high volumes for defence purposes, have a medium technology standard. As Intel-Magdeburg will not produce in this segment, the plant will not improve sovereignty regarding semiconductors for weapons systems. However, there are already some companies based in Europe, particularly in Germany, such as United Monolithic Semiconductors (UMS), which produce them. Overall, military demand for semiconductors is low compared to industry, accounting for around one to two percent of total demand, so there is less need for action here.

Regarding competitiveness, the European semiconductor industry is qualitatively competitive at the medium technology level. For example, Infineon is one of the leading semiconductor manufacturers in the automotive industry (Infineon 2024). In the production of leading-edge semiconductors, the Intel plant is likely to assume a monopoly position in the short term before two competitors, Samsung and TSMC, also enter the segment before 2030 (Böckmann 2024; Yu 2024).

In addition to the baseline scenario, we have tried to outline extreme but conceivable scenarios so that the range of the possible impact of the Intel plant on the European market becomes clear. However, it is unlikely that these two scenarios will occur in full.

In the baseline scenario, we expect Europe to slightly lose market share in industrial supply despite the planned plants due to the stronger expansion of semiconductor capacity in other regions. Europe is still best-positioned for chips with medium technology standards. These chips are in demand in the four main client industries. Nevertheless, even in this segment, demand clearly exceeds European production. The Intel plant's leading-edge chips are almost entirely claimed by Intel itself or other American companies. In Europe, there are few potential clients who will, in addition, not demand significant quantities. In terms of military sovereignty, the supply for weapons systems is largely covered by intra-European production, for example by ESMC and UMS. For AI accelerators, the design is still largely carried out by NVIDIA and production by TSMC in Taiwan. However, Intel can already secure a small market share, as the military wants to diversify its suppliers in the long term. The main supply from NVIDIA and TSMC should ensure supply without further intensifying geopolitical tensions, as the design is carried out in the USA and thus by a NATO partner and production in Taiwan is carried out by a country that is aligned with the West. In the event of a crisis, Intel could step in for production, although even in such a scenario it would take months to years to switch to Intel's new programming environment. Europe's competitiveness in the semiconductor industry will probably be slightly lower in 2035 than it is at present, as innovations in the main customer industries will develop such that chips with medium-sized structures will become slightly less relevant. The new Intel and ESMC plants will create new synergies in the leading-edge and logic semiconductor sector, further establishing eastern Germany as a relevant semiconductor technology hub. However, as the Intel plant focuses on mass production rather than chip design and knowledge transfer is more difficult in the semiconductor industry than in many other sectors, the strengthening of European competitiveness through the Intel plant is limited. Overall, the Intel plant in the baseline scenario therefore contributes to additional security of military supply and a strengthening of European competitiveness. Nevertheless, the increase in sovereignty is limited by the lack of demand for leading-edge chips in the European industry.

The European semiconductor upswing scenario is characterised by Europe being able to maintain its market share in production. Innovations in the four main client industries are developing in such a way that there is still demand for chips manufactured in Europe with a structure size of around 28 nanometres. In addition, some European clients, such as Sony Ericsson and Nokia, develop a relevant demand for leading-edge chips and source these from Intel-Magdeburg. Leading-edge chips also gain relevance in the automotive industry, for example for autonomous driving, and some European automotive companies source their chips from

Intel. In the defence sector, weapons systems are supplied entirely by European semiconductor manufacturers. In addition, Intel-Magdeburg already supplies a significant proportion of military AI accelerators. European competitiveness is strengthened by innovations, driven by synergy effects in the eastern German semiconductor cluster, such as cooperation between clients and producers. This also applies to the leading-edge sector, where technical advances in autonomous driving and at Nokia and Sony Ericsson can be made in collaboration with the Magdeburg Intel plant. In this scenario, Intel still supplies only a limited share of European customers, but plays a relevant role and contributes significantly to the development of new innovations in Europe that strengthen the entire European economy.

The Taiwan disruption scenario, on the other hand, represents a worst-case scenario for the European economy. The severely restricted supply of semiconductors from Taiwan and China would have a heavy impact on European industry. Only a small proportion of 5 to 10 percent of the requirements of the four main client industries can still be covered by European production. In addition, the leading-edge chips from Intel-Magdeburg can serve as a bargaining chip, for example with the USA, to obtain a limited additional quantity of chips of the medium technology standard, which would be demanded by the European industry. Nevertheless, there would be a slump in the industry. The military stockpile would not be restricted, and the expansion of weapons systems could be continued with some restrictions by European manufacturers. In the case of military AI accelerators, the expansion would be considerably restricted in the short term, but could be secured relatively quickly, for example through European pooling strategies, due to the lower demand volumes compared to industry. In the long term, Intel-Magdeburg can take over the supply after AI users have switched to the Intel programming system. If the leading-edge semiconductor plants in Taiwan were to be destroyed, the global technology standard would fall considerably. China could further expand its market leadership in this area thanks to its production capacities in the lower technology standard. In the long term, the Intel plant could help build a European semiconductor industry. This means that the Intel plant plays a more important role in this extreme case compared to the baseline scenario, but can only make a limited contribution to cushioning the catastrophic effects of a Taiwan disruption scenario.

6. Conclusion

The expected effects of the subsidy for Intel-Magdeburg are complex and cannot be reduced to a single conclusion. Table 2 provides an overview based on the eight mechanisms of the BESTInvest guidelines.

We believe that learning curve and cluster effects, the oligopoly position in leading-edge chip production and the lower cost of capital due to government subsidies will increase Intel's competitiveness, but will not completely eliminate the locational disadvantage in Germany. Whether the project would ultimately prove to be an economically worthwhile investment depends largely on the supply chain pull effects and other catalytic economic factors. Although these will be significant, their exact amount is difficult to predict, which is why our estimate contains a considerable element of uncertainty. The innovation and cluster effects of the investment could strengthen Germany as an innovative industrial country. Nevertheless, similar effects could probably be reached more efficiently by alternative investments and policy instruments rather than a large subsidy to a single semiconductor mass production plant. Since only a small number of jobs are created relative to the investment sum, and since these jobs are primarily within occupational groups where there are already shortages of skilled workers, we believe that other investments would also be more cost-effective in order to support the labour market.

Climate effects are difficult to evaluate with the available data. Overall, however, we expect a positive, albeit moderate contribution to global decarbonisation efforts. We also consider the Intel plant's contribution to European sovereignty to be positive but small.

Ultimately, a political decision is needed that weighs up the various aspects of the investment. Our analysis presents the different expected impacts of the investment and thereby provides inputs for such a political decision.

To further support this decision-making process, it is helpful to take a final comparative look at the amount invested by the state. At 9.9 billion euros, the support for Intel's new fab is not only the largest industrial policy subsidy for an individual company in Germany's history, but also comparable to the funds needed to achieve certain other political goals. For example, Heilmann et al. (2024) estimate that the additional public funding needed to raise the research share of German GDP to the target value of 3.5 percent for the years 2025 to 2030 would also amount to 9.9 billion euros.

Dimension	Mechanism	Effect
Whole economy	Learning curve effects	◑
	Cluster effects	◔
	Innovation effects	◔
Whole economy & regional economy	Supply chain pull effects	◕
	Private vs. public returns	◑
	Labour market effects	◔
Climate change	Countering externalities	◔
Sovereignty	Incomplete insurance markets	◑

Table 2: Evaluation of the mechanisms according to the BESTInvest guidelines; **source**: own calculations and analyses

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