The macroeconomic impact of Fraunhofer-Gesellschaft

A CGE approach, using micro-evidence

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The Fraser of Allander Institute

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The report was commissioned in 2020 by Fraunhofer-Gesellschaft.

The analysis and writing-up of the results was undertaken independently by the FAI. The FAI is committed to providing the highest quality analytical advice and analysis. We are therefore happy to respond to requests for technical advice and analysis. Any technical errors or omissions are those of the FAI.

Executive Summary

- This report analyses the impact of Fraunhofer-Gesellschaft activities on the German economy. To do so, we use a multisectoral dynamic macroeconomic model of Germany. We calibrate the model, using data from the National Accounts of Germany for 2016. These accounts represent transactions between industries, final demand, and international trade with the rest of Europe and the rest of the World.
- Microeconomic evidence from Schubert (2020) suggests that €1 spent on Fraunhofer budget corresponds to an approximate increase in German GDP of €21. We use this result in combination with information from Frietsch (2020) on collaboration between Fraunhofer and firms in the private sector to assess the impact of the privately funded portion of the Fraunhofer budget in 2016 and of the total 2016 Fraunhofer budget on the German economy.
- Our approach aims to capture the contribution of Fraunhofer activities to the German economy by comparing the baseline state of the economy in 2016 with two counterfactual scenarios, based on the GDP impact derived in Schubert (2020). The modelling results allow us to trace the propagation of these impacts on key macroeconomic indicators and industries for Germany.
- At the core of our analysis lies Scenario 1. This scenario simulates a 0.31% increase in German GDP, corresponding to the effect that the €410 million of private funding to Fraunhofer have on the economy. This is complemented by Scenario 2, which simulates a 1.6% GDP contribution, representing the effect of the total 2016 Fraunhofer budget (€2,081 million).
- Under both scenarios, Fraunhofer activities have significant macroeconomic effects on Germany. As expected, these effects are much larger when the entire budget is considered (Scenario 2).
- Scenario 1 is associated with a 0.21% contribution to employment and government revenue, as well as a 0.45% contribution to investment.
- Scenario 2 is associated with a 1.0% contribution to employment, a 1.1% to government revenue, and a 2.4% to investment.
- Under both scenarios, the impact on investment and government revenue exceed total Fraunhofer funding.
- The impact of Fraunhofer is concentrated in industries that can be notionally defined as "knowledge intensive" and that are of critical importance to the German economy. In particular, we find that the economic impact of Fraunhofer is concentrated in the chemical-pharmaceutical and the automotive-machinery sectors.

1. Introduction

The Fraser of Allander Institute (FAI) was commissioned by the Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. to model the effects of Fraunhofer activities on the German economy.

Fraunhofer was founded in 1949 with the aim of conducting cutting-edge applied research in Germany. Today, it is Europe's largest applied research organization, with 72 institutes in Germany, covering a wide range of topics, mainly in engineering and science.

We estimate the contribution of Fraunhofer activities on the German economy, using a Computable General Equilibrium (CGE) model. CGE models are large-scale quantitative models that represent the behaviour of key agents in an economy. They simulate the economic impact of policy interventions relative to an initial equilibrium. Thus, their results are counterfactual in nature rather than explicit forecasts. However, they are useful to illustrate the propagation of macroeconomic stimuli on key economic indicators such as GDP and wages, as well as sectoral employment, investment and value added, government revenue and international trade.

Within our model, we run heterogenous exogenous demand shocks that represent the contribution of Fraunhofer activities to the German economy. In response to these shocks, the economy will adjust to a new counterfactual macroeconomic equilibrium. The contribution of Fraunhofer activities on key economic variables, such as investment, employment, and government revenue, is estimated as the difference between the initial and the new equilibrium.

To estimate the size of these exogenous demand shocks and hence define our counterfactual simulations, we use a micro-to-macro approach. In particular, we leverage micro evidence from Schubert (2020) on the GDP effects of regional Fraunhofer funding. We complement this with data on Fraunhofer collaboration with the private sector from Frietsch (2020) to gauge the sectoral distribution of Fraunhofer impacts.

We simulate two heterogenous exogenous demand shocks, representing the additional economic stimulus that spending on Fraunhofer budget provides to the German economy, according to Schubert (2020). We refer to these shocks as Scenario 1 and Scenario 2. Scenario 1 simulates a 0.31% GDP increase, replicating the effects of 2016 private funding (€410 million) matched to specific industries. Scenario 2 simulates a 1.6% GDP increase, replicating the effects of the total 2016 Fraunhofer budget (€2,081 million). We employ this twofold approach because the available data on the economy-wide pattern of sectoral collaborations for Fraunhofer only covers the private funded budget considered in Scenario 1. Thus, Scenario 2 is an extrapolation of the effects of private collaboration towards the total (private and public) Fraunhofer budget.

We find that Fraunhofer activities contribute significantly to key economic indicators and industries. The funding considered by Frietsch (2020) creates a 0.21% increase in long-run employment and a 0.45% rise in investment. These effects cluster in knowledge-intensive industries, such as the automotive-machinery and chemical-pharmaceutical sectors. Scaling the effects to the entire Fraunhofer budget, we find an increase in employment of up to 1% and 2.4% in additional investment.

We add to the existing literature on economic effects of Fraunhofer (Bilsen et al., 2018; Comin et al., 2019; Schubert, 2020) by focusing on macroeconomic effects and using the latest available data. In addition, we develop a modelling framework that can be applied and extended to capture different aspects of the impact of Fraunhofer activities as outlined in section 6.

The reminder of this report is organized as follows. Section 2 presents the data we use in our analysis. Section 3 discusses our methodological approach. Section 4 presents aggregate and sectoral results from our simulations. Section 5 summarises our analysis. Lastly, Section 6 provides recommendations for future research.

2. Data

Our approach combines macroeconomic and microeconomic data. We use macroeconomic data to calibrate AMOS to an initial equilibrium, representing the German economy in 2016. Then, we use microeconomic data to estimate an exogenous demand shock, representing Fraunhofer contribution.

On the macroeconomic level, we use the National Accounts (Destatis, 2020a) and Input-Output tables (Destatis, 2020b) for Germany 2016 from the Federal Statistical Office of Germany to create a Social Accounting Matrix (SAM). To do so, we follow the methodology detailed in Emonts-Holley, Ross, and Swales (2014). A SAM is a matrix representation of the transactions between different sectors, factors of production, and their owners (Keuning and de Ruuter, 1988). Table 1 illustrates the structure of our SAM. Rows represent revenues and columns represent expenditures. The Sector/Sector field aggregates transactions of intermediate goods between industries in the economy. Final demand comes from household, government, investment, and exports. Labour and capital are used in the production process. Labour income goes to households, while capital income is divided between the government, firms, and households. We use the SAM to calibrate the baseline scenario of AMOS.

Table 1: Aggregated Structure of Social Accounting Matrix for Germany 2016

Receipts ↓ Expenditures →	Sectors	Labour income	Gross operating surplus	Net Indirect taxes	Households	Corporation	Government	Capital	Exports	Total
Sectors	3670497	-	-	-	1283831	-	597692	427562	1177041	7156623
Labour income	1622780	-	-	-	-	-	-	-	-	1622780
Gross operating surplus	1202093	-	-	-	-	-	-	-	-	1202093
Net Indirect taxes	69796	-	-	-	177077	-	7753	54601	-	309227
Households	-	1622780	375733	-	-	702390	543995	-	104060	3348958
Corporation	-	-	713806	-	202212	-	154957	-	172249	1243224
Government	-	-	112554	309227	955451	83166	-	-	-134398	1326000
Capital	-	-	-	-	339919	345885	7034	-	-59321	633517
Imports	591457	-	-	-	390467	111783	14569	151355	648037	1907668
Total	7156623	1622780	1202093	309227	3348957	1243224	1326000	633518	1907668	

Source: *FAI elaboration based on Destatis (2020a) and Destatis (2020b)*

The Sector/Sector field in Table 1 can be further disaggregated to understand interlinkages in the German economy. For the purpose of this analysis we consider 28 aggregated industries as illustrated in Table 2. The 28 sectors shown reflect the structure of Fraunhofer collaboration, as well as major activities within the German economy.

Table 2: List of 28 Sectors in Social Accounting Matrix for Germany 2016

Code	Name
S1	Agriculture
S2	Mining and Raw Materials
S3	Oil and Gas (incl. refining)
S4	Metal Products
S5	Iron and Steel Products
S6	Rubber and Plastic
S7	Wood and Paper Products
S8	Ceramics and Stone Products
S9	Chemicals
S10	Pharmaceuticals
S11	Computers, Electronics, and Opticals
S12	Electrical Equipment
S13	Machinery
S14	Motor Vehicles
S15	Other Transport Equipment
S16	Other Manufacturing
S17	Gas, Water, and Electricity Supply
S18	Construction
S19	Publishing, Media, and Culture
S20	ICT Services
S21	Finance and Insurance
S22	Services for Firms
S23	Research and Development
S24	Health Services
S25	Wholesale and Retail
S26	Transportation Services
S27	Other Services (Private)
S28	Other Services (Public)

Source: *FAI Definition*

On the microeconomic level, we utilize data and estimates provided by researchers from the Fraunhofer Institute for Systems and Innovation Research, ISI, to inform the simulation scenarios.

In particular, we use econometric estimates from Schubert (2020). Based on panel data for the 2003 - 2017 period, Schubert estimates the GDP effects of Fraunhofer activities. The author finds that each €1 additional Fraunhofer budget is associated with between €21.13 and €21.67 increase in German GDP, depending on the econometric specifications. Schubert finds evidence that the channel for this effect is increased demand, rather than improved productivity. Hence we model Fraunhofer activities as an expansion of the demand-side of the Germany economy.

We complement these estimates with data provided by Frietsch (2020) to understand the sectoral composition of Fraunhofer impact. Frietsch (2020) matches Fraunhofer's internal data for the volume of private sector funding with the Bureau van Dijk's Orbis company database, which matches companies and sectors. Table 3 depicts the resulting sectoral distribution of research contracts, covering 60% of private sector funding for the 2015 - 2019 period. We observe that companies within the Machinery (S13), Motor Vehicles (S14), and Services sectors (S22 and S27) exhibit the highest cooperation intensity with Fraunhofer.

Table 3: Sectoral Distribution of Private Sector Fraunhofer-Gesellschaft Funding, 2015 - 2019. Compiled from Frietsch (2020)

Code	Name	Project Volume in Euro	Share
S1	Agriculture	288,500	0.03%
S2	Mining and Raw Materials	45,892,797	4.23%
S3	Oil and Gas (incl. refining)	472,943	0.04%
S4	Metal Products	40,470,742	3.73%
S5	Iron and Steel Products	7,539,866	0.70%
S6	Rubber and Plastic	10,272,145	0.95%
S7	Wood and Paper Products	-	0.00%
S8	Ceramics and Stone Products	15,416,557	1.42%
S9	Chemicals	63,404,607	5.85%
S10	Pharmaceuticals	29,573,181	2.73%
S11	Computers, Electronics, and Opticals	92,871,374	8.56%
S12	Electrical Equipment	28,983,539	2.67%
S13	Machinery	94,036,439	8.67%
S14	Motor Vehicles	167,572,759	15.45%
S15	Other Transport Equipment	30,345,708	2.80%
S16	Other Manufacturing	3,398,011	0.31%
S17	Gas, Water, and Electricity Supply	27,944,997	2.58%
S18	Construction	-	0.00%
S19	Publishing, Media, and Culture	5,474,226	0.50%
S20	ICT Services	50,842,261	4.69%
S21	Finance and Insurance	40,654,125	3.75%
S22	Services for Firms	105,424,784	9.72%
S23	Research and Development	69,931,959	6.45%
S24	Health Services	2,762,461	0.25%
S25	Wholesale and Retail	-	0.00%
S26	Transportation Services	-	0.00%
S27	Other Services (Private)	150,855,073	13.91%
S28	Other Services (Public)	-	0.00%
	Total matched private sector funding	1,084,429,054	100.00%
	Total private sector funding	1,805,908,963	

Source: *Frietsch 2020*

3. Methodology

For the application at hand, we use the AMOS CGE model. Researchers at the FAI developed this model in the late 1980s (e.g. Harrigan et al., 1991) and it has been extensively extended and applied since then. The AMOS model combines economic theory and data to capture interlinkages between domestic firms, a government, the private sector, households, and foreign trade partners[1]. It has been applied by academics and the public sector, such as by the governments of Northern Ireland and Scotland, to capture the effects of a diverse set of policies, including Brexit (Figus et al., 2016), Universal Basic Income (Connolly et al., 2020), renewable energy expansion (Allan et al., 2020), and higher education (Hermannsson et al., 2014). We calibrate the model to reflect the current state of the German economy, using 2016 National Accounts data from the German Federal Statistical Office (Destatis, 2020a; Destatis, 2020b).

Within this representation, we simulate exogenous demand shocks, representing the additional contribution of Fraunhofer activities on GDP, based on microeconomic findings from Schubert (2020). Essentially these shocks simulate a counterfactual German economy where GDP is exogenously increased to match the microeconomic evidence. The shocks are heterogenous across sectors, meaning that the impact to each sector of the German economy is weighted by Fraunhofer collaboration intensity, as given in Table 3. Thus, we assume that private sector collaboration proxies the relative impact of Fraunhofer activities.

To estimate the total size of exogenous demand shocks, we assume that additional Fraunhofer budget has a causal impact on German GDP. This effect is modelled to be linear in budget. Thus,

$$\Delta GDP = \gamma B, \tag{1}$$

where ΔGDP is the absolute change in GDP, B is the budget for Fraunhofer activities, and γ is the effect of Fraunhofer budget on GDP. Schubert (2020) estimates γ to be in the range of €21.13 - €21.67.

From this, we derive two distinct exogenous demand shocks. The first shock, referred to as Scenario 1, simulates the knock-on effect of a subset of Fraunhofer budget (€410 million) that we can map to specific sectors, using data provided by Frietsch (2020). This scenario forms the core of our analysis, as we know the underlying distribution of the corresponding budget. The second shock, Scenario 2, simulates the knock-on effect of the entire 2016 budget (€2,081 million). Scenario 2 is an extrapolation of Scenario 1 because it assumes that aggregate Fraunhofer effects are distributed in line with the private sector funding.

Plugging these numbers into equation 1 and dividing the results by total 2016 GDP, we find that Scenario 1 is associated with a 0.31% GDP increase and Scenario 2 with a GDP increase of 1.6%. Table 4 summarizes the parameters for both exogenous demand shocks.

Next, we compare the long-run equilibria of the economy with and without these exogenous demand shocks to calculate the impact of Fraunhofer activities.

1 The interested reader can find a more technical discussion of AMOS in Lecca et al. (2009, 2014).

Table 4: Parameters for exogenous demand shock. Scenario 1 simulates the effects of matched private sector funding. Scenario 2 simulates the effects of the entire budget.

Variable	Value in 2016	Source
GDP	€2821.803 billion	Destatis (2020a)
Fraunhofer Budget	€2.081 billion	Fraunhofer Jahresbericht (2016)
Matched Private Sector Funding	€410 million	Frietsch (2020); Fraunhofer Jahresbericht (2016)
GDP Effect of €1 Budget	€21.13 to €21.67	Schubert (2020)
Total effect of Fraunhofer Budget	1.6%	(Fraunhofer Budget * GDP Effect) / GDP
Total effect of matched private sector funding	0.3%	(Matched funding * GDP Effect) / GDP

4. Results

In this section, we provide aggregate long-run effects on key economic variables for Scenario 1 (private funding) and Scenario 2 (entire budget). In addition, we provide sectoral long-run effects for Scenario 1, as we know the underlying distribution of the budget covered by this shock. This allows us to gauge the macroeconomic impacts of Fraunhofer activities and their distribution across sectors of the Germany economy.

4.1 Aggregate Effects

This section focuses on the aggregate counterfactual effects of Fraunhofer activities. The long-run effects of Scenario 1 and 2 on Employment, Investment and Government Revenue are provided in Table 5. We consider each effect in turn. As expected, the total effects for the entire budget (Scenario 2) are much larger than the effects of the considered private sector funding (Scenario 1).

In 2016 there where about 43.7 million people in employment in Germany (Destatis, 2016b). Under Scenario 1, this number increases by 0.21% in our model, creating about 92 thousand additional jobs in the long run. In section 4.2. we analyse the sectoral composition of these jobs. Scenario 2 creates 1.0% additional employment, which equals about 437 thousand jobs.

Next, we consider investment effects. In 2016, there was €634 billion investment into German capital (Destatis, 2016b). Scenario 1 estimates that this rises by 0.45% or €2.85 billion in response to private Fraunhofer funding covered. This corresponds to a 2.4% increase or €15.2 billion in Scenario 2. Thus, even the more robust investment effect under Scenario 1 outweighs total Fraunhofer funding.

Lastly, we consider the impact of Fraunhofer activities on government revenue. Under scenario 1, government revenue increases by 0.21%, which is about €2.7 billion. The entire budget (Scenario 2) is associated with an increase of 1.1% in government revenue. This corresponds to about €14 billion. These increases are mainly driven by additional taxes on labour (note how the proportionate increase in employment roughly corresponds to the proportionate increase in government revenue) but the government also increases its income from capital taxes. Thus, there appears to be a significant tax multiplier for Fraunhofer investment.

Table 5: Estimated effects of Fraunhofer private funding and total budget on key economic variables

Change under	Scenario 1	Scenario 2
GDP	0.31%	1.6%
Employment	0.21%	1.0%
Investment	0.45%	2.4%
Government Revenue	0.21%	1.1%

Source: *FAI Calculation*

4.2. Sectoral Effects

In this section, we illustrate how impacts from Scenario 1 are distributed across the 28 sector aggregation of the Germany economy considered in this analysis. As a reminder to the reader, in this scenario we only consider the €410 million private sector funding portion of total Fraunhofer budget mapped to specific sectors (see Table 3). Assuming that private sector collaboration proxies the industrial pattern of the demand effects, this allows us to estimate where in the economy Fraunhofer effects are concentrated.

Figure 1 depicts percentage changes in total output by industry, Figure 2 considers value added, Figure 3 employment, while Figure 4 shows investment. We observe that the impact distribution of these key economic variables is very similar across the different macroeconomic indicators, and they are mostly positive. The only exception is a small fall in output in sector 1 (Agriculture) and sector 7 (Wood and Paper products). This is because factors of production are constrained in our model and are moved towards more productive sectors in response to the shock. In addition, the increased demand puts upward pressure on prices thereby dampening the increase in demand for domestic output.

Table 6 reports the sectors with the largest increases in output. Many of these sectors, such as Motor Vehicles and Machinery sectors, are of critical importance to the German economy, highlighting the crucial nature of Fraunhofer activities.

Table 6: Five sectors with largest impact on total output under Scenario 1

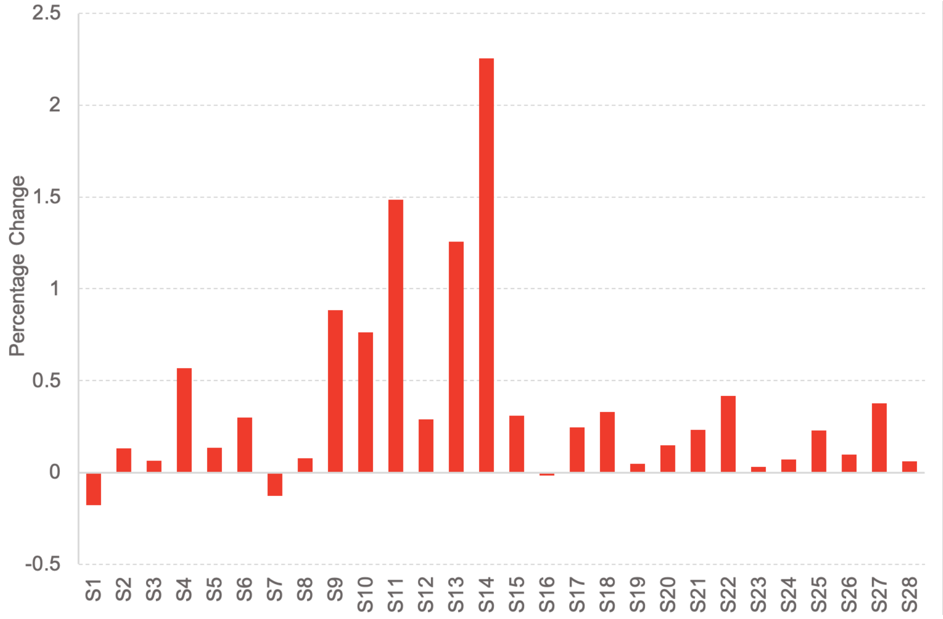
Sector	Output Change
Motor vehicles (S14)	2.3%
Computers, Electronics, and Opticals (S11)	1.5%
Machinery (S13)	1.3%
Chemicals (S9)	0.9%
Pharmaceuticals (S10)	0.8%

Source: *FAI Calculation*

Combined, the Motor Vehicle and Machinery sectors employ 1.543 million people in Germany (Destatis, 2016b). Under Scenario 1, employment in these sectors rises by 2.1%, and 1.3% respectively. This corresponds to about 25 thousand additional jobs. There is also significant additional investment in these sectors. Investment in the Motor Vehicle sector rises by 2.2%, while investment in the Machinery sector rises by 1.2%.

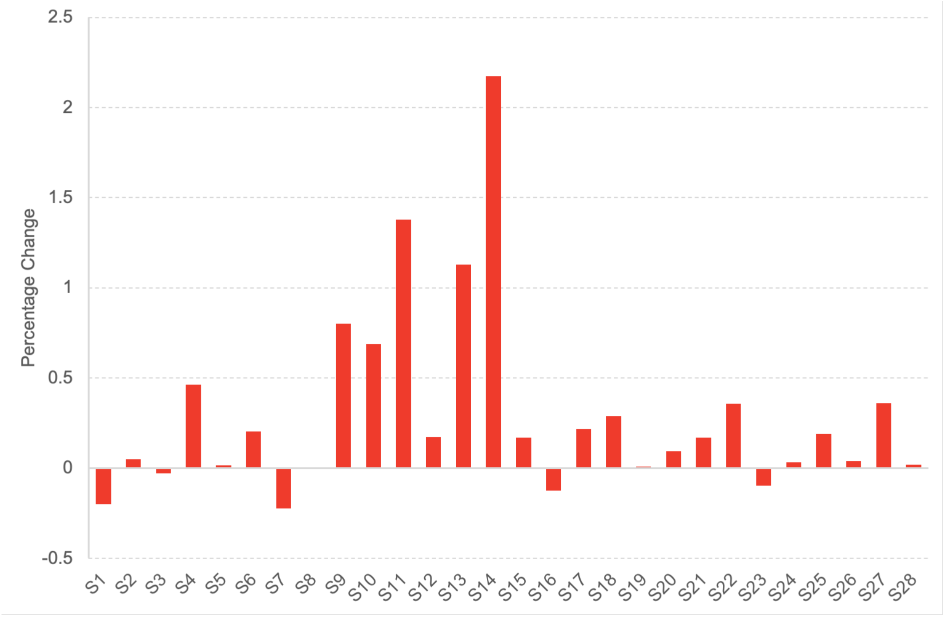
With many world-leading companies, such as Bayer and BASF, the chemical-pharmaceutical industries are also of critical importance to the German economy. Here, Fraunhofer activities create 0.7% additional employment in the chemical industry and 0.6% additional employment in pharmaceuticals. These industries also see an increase in investment of 0.9% and 0.7%, respectively.

Chart 1: Percentage change in total output by industry, 2016



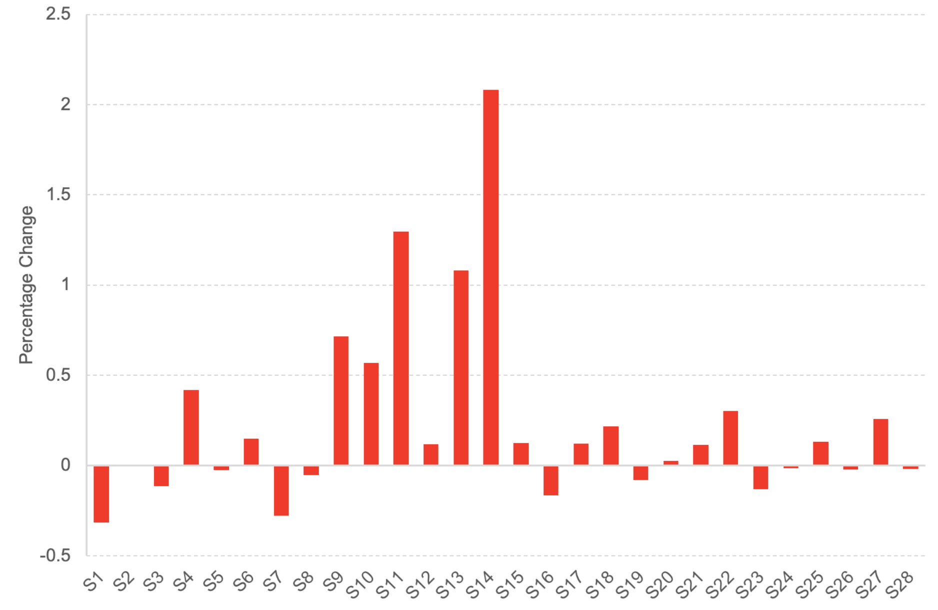
Source: *FAI Calculations*

Chart 2: Percentage change in gross value added, 2016



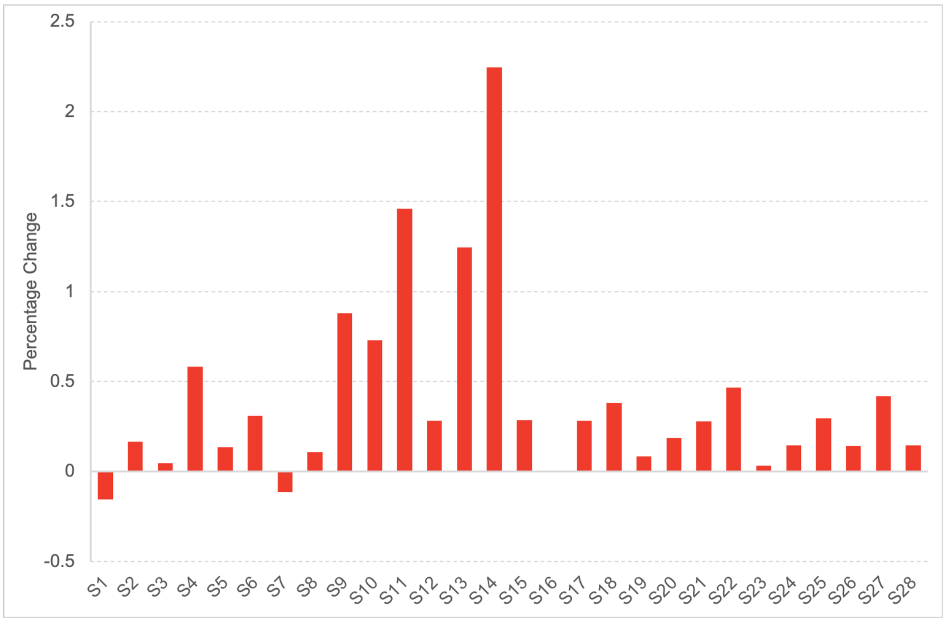
Source: *FAI Calculations*

Chart 3: Percentage change in total employment by industry, 2016



Source: *FAI Calculations*

Chart 4: Percentage change in total investment, 2016



Source: *FAI Calculations*

5. Conclusions

In this report, we have shown the significant contribution of Fraunhofer-Gesellschaft activities on the German economy.

We make use of a newly-developed Computable General Equilibrium model of the German economy that has been specifically created for this project.

To illustrate the contribution of Fraunhofer-Gesellschaft we have looked at two simulations – i) an assessment of the impact of the €410 million in private funding that Fraunhofer leveraged in 2016; and ii) an assessment of the impact of the full effect of the €2,081 million (for 2016) budget of Fraunhofer.

Under both scenarios, Fraunhofer-Gesellschaft activities have significant macroeconomic effects – including a 0.2% and 1.0% increase in employment relative to what it would otherwise have been respectively.

In both scenarios, the impact on investment and government revenue exceed total Fraunhofer funding.

6. Future Research

Whilst the primary aim of the project was to identify the economy-wide contribution of Fraunhofer-Gesellschaft on the German economy, this project also delivers a working CGE model of Germany that can be utilised and extended in a number of ways. Some examples are listed below.

- The model is set up to capture improvements in productivity driven by the additional knowledge created by interactions between Fraunhofer and German firms. While microeconomic evidence of productivity impacts was not available at the time of this analysis, this could become available in the future.
- The model could be augmented by including endogenous productivity improvements driven by learning-by-doing functions.
- The research and development industry in the German IO tables could be disaggregated to identify Fraunhofer separately from the other industries. This could then be modelled appropriately in the CGE framework. This would, however, only identify the demand- or supply-consequences of Fraunhofer's own purchases and sales, and not the effect on businesses which work with Fraunhofer and whom might be expected to see increased demand or expanded productivity from these interactions, for instance.
- Information about greenhouse gas emissions and other environmental indicators could be used in combination with the IO accounts and the CGE model to capture the environmental impact of Fraunhofer.
- Finally, the national economy could be decomposed into a set of sub-regions to better identify spatial and local impacts, subject to such economic data being generated.

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