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Shocking a CEO: Economic Disintegration and Executive Compensation in Manufacturing and Services Firms

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Shocking a CEO: Economic Disintegration and Executive Compensation in Manufacturing and Services Firms^{*}

Abstract

This paper uses the Brexit referendum in 2016 as a quasi-natural experiment to estimate the effect of an exogenous negative shock to globalization on executive compensation for German companies listed in the DAX and MDAX stock indices. We show that it matters whether they work for firms exporting goods or services. The main results indicate that executive compensation in firms operating in sectors that export services was negatively affected, in particular through lower variable compensation. On the contrary, executives of firms that operate in sectors exporting goods were not negatively affected overall, though they experienced a compositional change (from bonuses to equity payments). Sectoral regressions suggest that manufacturing firms redirected successfully exports from the UK to other relevant trade partners, while this was not the case in the service sector.

JEL classification

F14, F16, E24, J33, G35

Keywords

Brexit, executive compensation, disintegration, services

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1 Introduction

How does the remuneration of top executives in internationally operating firms respond to negative shocks to global economic integration? We know that, in the era of globalization, executives have seen their compensation packages increase as a result of such global integration, both in absolute terms and relative to the average pay of "normal" workers (Ma & Ruzic, 2020; Keller & Olney, 2021). However, the last two decades, starting with the financial crisis in 2008 have seen many negative shocks to integration. And this trend towards disintegration seems, if anything, to be accelerating since the Covid pandemic in 2020 and rising geopolitical tensions. How does this affect executives as the top earners in an economy? This is the question we address in this paper.

For our empirical analysis, we exploit an unexpected and arguably exogenous shock to international integration, namely, the Brexit referendum in 2016. We investigate how this unexpected signal towards economic disintegration between the UK and the EU affected compensation for executives in German DAX and MDAX listed firms, using executive-firm level data for 2006 to 2020. This paper is, to the best of our knowledge, the first that investigates the link between such an exogenous negative shock to globalization and executive compensation.¹

The United Kingdom (UK) – European Union (EU) membership referendum on 23 June 2016, usually referred to as Brexit referendum, has been widely considered as an unexpected exogenous shock that increased uncertainty about future trade policy, and bilateral trade between the EU and the UK. The result of the vote was unexpected, with opinion polls up to the night of the vote showing a small majority for the "remain" vote. In the referendum, 51.9% of voters were in favor of the UK leaving the EU. As a result, the UK formally triggered exit proceedings on 29 March 2017, but it did not leave the EU formally before 31

¹Ma and Ruzic (2020) use the accession of China to the WTO as a positive shock to integration, and look at the impact on executive compensation. Keller and Olney (2021) use an instrumental-variables strategy in a period where globalization also increased. Lie and Yang (2023) focus on the impact of import competition from China for US executives. These papers look at the US, and only consider trade in goods.

January 2020. Hence, the referendum was separated by more than three and a half years from the actual withdrawal from the EU. This is the post-referendum period we consider in this paper.

We investigate what happened in firms in Germany, an important trade partner of the UK within the EU. This links our work to other papers that look at the impact of the Brexit referendum on trade partners. For example, Fernandes and Winters (2021) use Portuguese firm level in a difference-in-differences set-up to show that Portuguese exporters reduced volumes and prices for exports to the UK following the referendum. Graziano et al. (2021) use bilateral UK – EU trade data and also document the negative impacts of the trade policy uncertainty generated by the Brexit referendum. Focusing on the UK rather than trade partners, Crowley et al. (2020) show that British firms export fewer new products to the EU following the referendum, while, more generally, Bloom et al. (2019) document a reduction in investment and employment growth in British firms as a result of the referendum. We provide a new angle to the literature on the implications of the Brexit referendum, focusing on what happened to top managers in firms in a trade partner country, Germany.

An important novelty and contribution of our paper is that we distinguish firms and executives in manufacturing and services sectors, and consider trade in goods and services. Hence, uniquely, we can look at the different ways manufacturing and service firms adjust to exogenous trade shocks.² This links our work to papers that study both sectors from different perspectives, like comparing the characteristics of firms trading goods or services (e.g., Ariu, 2016; Breinlich & Criscuolo, 2011), looking at service sales by manufacturing firms (e.g., Ariu et al., 2019; Grover & Mattoo, 2021; Gu et al., 2020), or estimating the impact of services availability on manufacturing firm performance (e.g., Arnold et al. 2011; Debaere et al., 2013; Shepotylo & Vakhitov, 2015, Görg & Jabbour, 2016). We complement these studies by looking at the heterogeneous impact of a negative trade shock on firms

²Yahmed and Dougherty (2016) analyzes the import penetration impact on firms' productivity in several industries, including manufacturing and services, without performing a heterogeneity analysis.

trading goods and services.³

We would expect differences due to the nature of the products traded. This matters for executive compensation. We can illustrate this point adopting the conceptual framework by Ma and Ruzic (2020), where the basic idea is that executive compensation is to some extent linked to the sales of the firm, while the wages for production workers are set in a country-wide labour market. Hence, a trade shock can influence executive compensation through changes in firms' output. If the shock is positive, executive compensation should rise faster than pay for average workers, which is what Ma and Ruzic (2020) and Keller and Olney (2021) find. In the case of a negative shock, firms may try to readjust their export activity and redirect exports to other destinations (including the domestic market). If this is done successfully, then executive compensation may not be negatively affected.

Our working hypothesis is that such adjustments are easier for goods than for services trade. While a pharmaceutical that was previously sold to the UK may be easily sold to other markets, this may be far more difficult for a business or financial service. Not only are services more likely to be tailored to the customers, but services trade restrictions may prohibit an easy redirection of services exports away from the UK to other markets. This also reflects arguments in the *World Trade Report 2019* (WTO, 2019) which points out that trade barriers for services are much higher than for goods trade, mainly due to regulatory differences. A similar point is made by Bernasconi et al. (2025) for the case of the EU Single Market, where they argue that services markets remain far less integrated than markets for goods, which severely impedes trade in services.

Our results suggest that there are indeed differences between services and goods traders, in line with the above arguments. In our descriptive analysis we document a negative impact of the Brexit-referendum on German sector-level services as well as goods exports to the UK, in line with Fernandes and Winters (2021) or Graziano et al. (2021). However, while we

³Overall, there is an imbalance in the literature with only few papers analyzing the impact of trade shocks in the services sectors (Bombarda et al, 2010; Hijzen et al, 2011; Christen et al, 2019) in comparison to the abundant literature for the manufacturing sector.

observe a negative impact of the Brexit-referendum on overall German services exports, this is not the case for goods exports. This differential impact on export performance motivates our research question, where we aim to see whether executives in services firms are affected differently from goods exporters in terms of their compensation packages.

We use a difference-in-differences approach that uses the Brexit referendum in 2016 as an exogenous shock, where we compare executive compensation of firms in sectors that are highly exposed in their pre-referendum export activity to the UK market and those with less exposure, before and after the referendum.⁴ We find that the compensation of German executives in sectors exporting services was negatively affected. Distinguishing variable and fixed components of pay, we find that the negative impact is concentrated on variable pay, which is reduced significantly. Interestingly, in an extension to our empirical model, we also find that the CEO-to-worker pay ratio increased as a result of Brexit in the services sector, hence, there is a rise in inequality. This suggests that wages of the average worker fell proportionally more than executive compensation. By contrast, executives in manufacturing firms were not affected negatively in their total, variable or fixed compensation. In the same way, the CEO-to-worker pay ratio in the manufacturing sector did not change due to Brexit.

These results appear to be driven by the inability of services firms to adjust their exports. While we show that manufacturing firms are able to increase overall exports in the wake of the Brexit referendum, and adjust export destinations (in particular increasing exports to the rest of the EU), this is not the case for services firms. Hence, it seems that German manufacturing firms successfully implemented a "redirecting exports strategy", switching exports destined to the UK to other clients, like other EU countries. This paid off for executives in terms of avoiding losses to compensation.

⁴Note that we do not have firm level export data available. Furthermore, the difference-in-differences econometric approach implemented in this paper focuses on the Brexit effect via exports, not imports, since Brexit affected in higher proportion German exports to UK than German imports from UK (see figures 4 and 13 and Section 3). However, most of the main results are robust when sectoral import shares from the UK are included as covariates in the baseline specification.

2 Data and descriptives

2.1 Data

In order to look at the link between economic disintegration and executive compensation, we merged data from different data sources.

Executive compensation: Information on executive pay at the level of the individual is obtained from the "German executive compensation database" constructed by Beck et al. (2020).⁵ This database contains the fixed compensation (salary, fringe benefits and personal benefits) and variable compensation (equity -stock and option grants-, one-year bonus, and multi-year bonus) for executives of firms listed in the DAX and MDAX stock indices. The database contains on average 76 firms per year and 5 executives per firm per year for the 2006-2020 period. Details on the collection of this data are provided in Beck et al. (2020).

Industry level exports: In order to see how German exports have developed over the period in question, we use data on industry level exports by destination, obtained from various Eurostat datasets. The data allow us to distinguish manufacturing and services trade. Further information on the datasets used, and the construction of the variables, is detailed in Appendix C.

Firm level data: Finally, in order to link the compensation data also to firm level outcomes, we obtain firm level data from the Worldscope database (Thomson, 2007). The link of the Worldscope data with the executive compensation dataset is done through the *ISIN* (International Securities Identification Number).⁶ For the linked DAX and MDAX firms, we obtain information on the number of employees, average wages, total assets value, CAPEX (capital Expenditures), return and leverage rates relative to assets and dividend declared per share. Unfortunately, the data do not include information on exports or imports at the

⁵We are very grateful to the authors for sharing their data with us. While Beck et al. (2020) show descriptive statistics for 2006 to 2018, the data they shared cover 2006-2020.

⁶95.7% of the firm-year observations in Beck et al. (2020) merged satisfactory with Worldscope; 3% were not in Worldscope and 1.3% had incomplete information.

firm level, which is why we rely on the industry level data as outlined above. Furthermore, we obtain one SIC (Standard Industrial Classification) code of the principal product of the firm, which is used to classify the main industry of the firm.⁷

Table 1 shows basic descriptive statistics for the companies listed in the DAX and MDAX stock indices distinguished by industry.⁸ Companies are large, though there is substantial heterogeneity across industries, ranging from an average of just over 200,000 employees in the motor vehicles sector to 424 in R&D services. There are also significant differences in the CEO pay relative to the remuneration of the average worker. In the retail and the textile industries this ratio is around 100 (implying that the CEO earns 100 times what an average worker is paid), compared to 15 in R&D services. This also reflects skill differences for workers in these industries, as suggested by the average wage which is about four times higher in R&D services than in retail.

⁷We assign one NACE Rev 2 code for manufacturing firms and one EBOPS 2010 code for services firms based on the SIC (Standard Industrial Classification) code reported by Worldscope and public information of firms. However, this assignment involves subjective criteria. For those firms whose SIC code was considered accurately aligned with the most important product/service sold by the firm (according to the firms' web pages), the assignment is subjective since there is no official concordance between SIC and NACE Rev 2 and SIC and EBOPS 2010. For those firms whose SIC code was not considered accurately aligned with the most important product/service sold by the firm (according to the firms' web pages), the assignment is also subjective since the most important product/service described in the firms' web pages could be accurately linked to different industry codes. The single-industry assumption per firm could be debatable since these large firms could operate in many industries (even spanning both manufacturing and services). However, this assumption tends to prevail in the literature even in topics that could be driven by few and large firms, including executive compensation (Keller and Olney, 2021) or innovation (Liu and Ma, 2020) .

⁸Real measures are calculated based on the consumer price index from Destatis Statistisches Bundesamt. 2020 is the base year.

Table 1: Firm descriptive statistics by industry sector

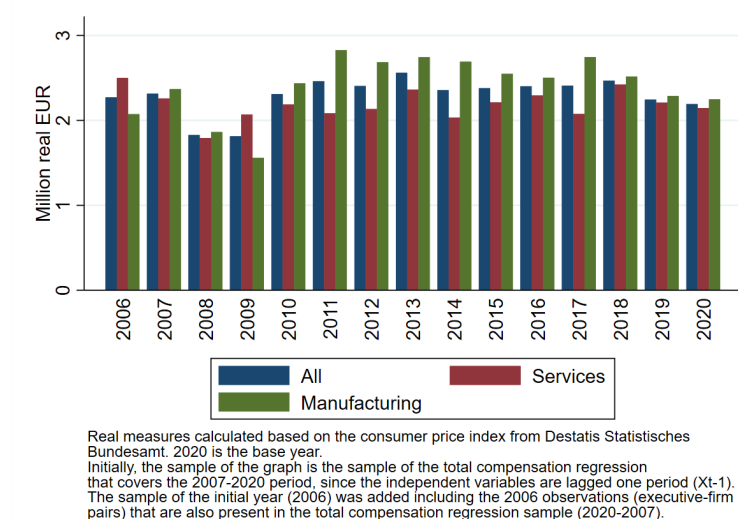
Sector	No. firms	L	Total <i>Assets</i> ¹ (million)	Avg <i>wage</i> ¹ (thousands)	CAPEX <i>rate</i> ²	<i>ROA</i> ²	Leverage <i>rate</i> ²	Dividend per share	CEO(max) ³ - to -avg worker pay ratio
Financial	4	26,377	353,524	112	0.1	0.8	20.9	0.4	32
Insurance and pension	3	54,107	321,747	74	0.1	1.0	4.0	5.9	63
Manufacture of motor vehicles, trailers and semi-trailers	4	201,396	192,481	80	4.0	3.3	44.8	2.4	78
Manufacture of other transport equipment	2	60,562	41,288	85	3.0	3.9	13.1	1.0	40
Manufacture of rubber and plastic products	1	189,886	32,321	45	7.1	4.9	27.5	2.3	81
Manufacture of pharmaceutical products	3	44,582	28,610	81	2.5	5.3	29.5	1.0	55
Transport	4	82,495	23,882	52	7.0	3.8	26.2	0.7	54
Telecommunication, computer and information services	6	41,440	17,460	78	3.2	5.7	34.1	0.7	51
Manufacture of electrical equipment	3	86,518	16,668	50	6.6	4.9	24.0	1.2	86
Personal, cultural and recreational services	4	78,518	16,529	47	3.8	6.2	32.1	0.5	81
Construction	2	59,185	12,025	66	3.7	2.3	21.1	2.5	51
Manufacture of other non-metallic mineral products	2	21,415	11,274	55	6.5	4.6	32.5	0.7	83
Manufacture of basic metals	3	30,325	10,635	67	4.6	3.5	12.9	0.5	25
Technical, trade-related and other business services	8	1,538	10,473	73	4.2	5.1	45.0	0.7	25
Manufacture of chemicals	9	17,126	8,052	76	5.2	6.8	22.4	1.0	49
Manufacture of textiles, wearing apparel, and leather products	2	30,877	8,023	42	5.2	9.9	17.0	1.4	99
Manufacture of computer, electronic and optical products	2	22,431	5,294	63	9.2	6.6	12.8	0.2	41
Retail	5	17,032	5,048	38	3.5	4.6	20.6	0.8	105
Manufacture of fabricated metal products	2	15,714	4,219	65	4.6	4.7	17.4	1.5	40
Manufacture of machinery and equipment n.e.c.	5	11,974	3,225	67	2.8	4.9	17.8	0.5	39
Professional and management consulting services	1	6,974	2,074	41	7.0	4.2	25.2	1.3	69
Manufacture of wood and of products of wood and cork	1	5,648	1,971	53	8.7	-7.0	66.0	0.1	27
Manufacture of coke and refined petroleum products	1	5,378	1,904	62	6.8	14.4	0.8	0.9	40
Research and development services	1	424	751	159	0.5	-9.3	7.4	0.0	15

Notes: We report the simple average of the total number of firms per year. For the rest of variables, it is reported the simple average of the median per year. Descriptive statistics at firm level are calculated on the sample of the net sales regression (table 8). ¹ Real EUR. ² Relative to assets. ³ Total compensation of the top earner executive.

2.2 Descriptive analysis

We start our analysis by looking at the development of executive compensation between 2006 and 2020. Figure 1 shows that the total average compensation for executives in German DAX and MDAX listed firms fluctuated substantially over that period.⁹ There was a decline during the financial crisis 2008 / 2009 followed by a quick recovery, reaching a peak in 2013. There has again been a decline in 2019 / 2020 which was also experienced in countries like the UK and the US, partly explained by the Covid pandemic.¹⁰ Average compensation in manufacturing firms appears somewhat higher than in services firms, though this difference has declined in the most recent sample years.

Figure 1: Total executive compensation (simple average), 2006-2020



Figures 2 and 3 zoom in on the components of total executive pay, distinguishing levels of variable and fixed compensation. This indicates that, broadly speaking, the level of variable compensation has declined somewhat in recent years, while fixed compensation has increased

⁹The composition of firms changes over the sample period. On average, each firms appears 8 years in the sample. Only 34 firms have observations in all of the 15 sample years. However, the trends shown in Figure 1 do not change if we just use data on these 35 firms. Moreover, the picture looks similar if we look at the median rather than the simple mean. Results are not reported here but can be obtained upon request.

¹⁰See "What happened to CEO pay in 2020?" <https://trustforlondon.org.uk/research/what-happened-to-ceo-pay-in-2020/>; "S&P 500 CEO Compensation Increase Trends" <https://corpgov.law.harvard.edu/2024/02/17/sp-500-ceo-compensation-increase-trends-6/>

in the early 2000s and remained fairly constant since then. Differences between executives in manufacturing and services firms are mostly observable in terms of variable, less so in terms of fixed compensation.

Figure 2: Variable compensation (simple average), 2006-2020

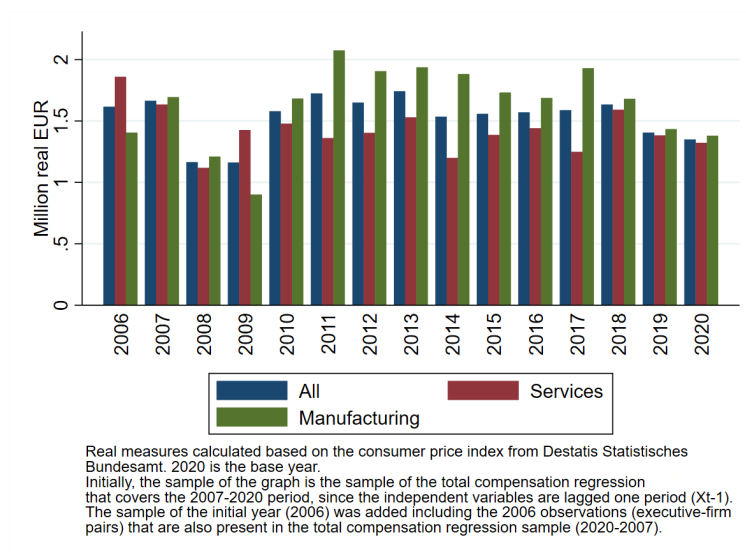
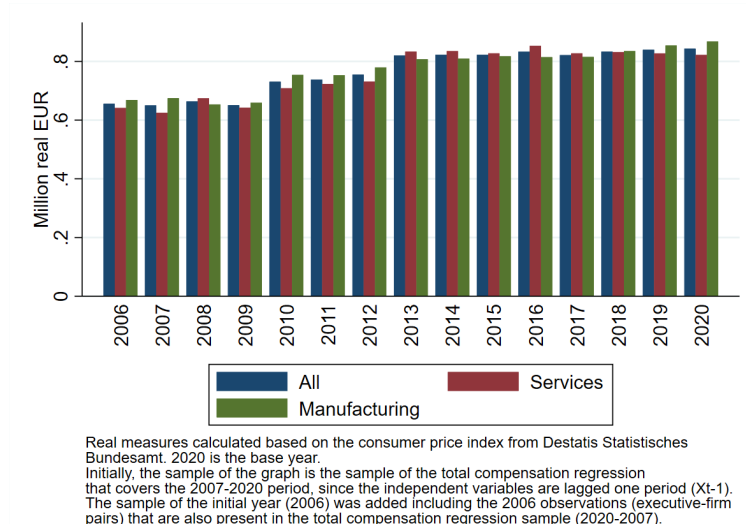


Figure 3: Fixed compensation (simple average), 2006-2020



Whether and how such developments and variations of the total compensation and its components (variable and fixed compensation) may be related to changes in economic dis-integration due to the Brexit referendum is an open question, that we aim to address in the

remainder of this paper.

To get a first idea of how the Brexit referendum impacted exports, Figure 4 shows the total value of German exports to the UK and to the rest of the world (panel a and b respectively) from 2006 to 2020. We distinguish services and manufacturing industries. For manufacturing industries, we clearly see a sharp decline in exports to the UK after 2016, with exports dropping from roughly 80bn to 60bn euro. While exports to the rest of the world continue increasing after 2016 before also declining in 2020 (most likely due to the Covid pandemic). The picture is less pronounced for services industries, where exports to the UK declined only very slightly after 2016, while they increased somewhat to the rest of the world.¹¹

Figure 4: German exports, 2006-2020.

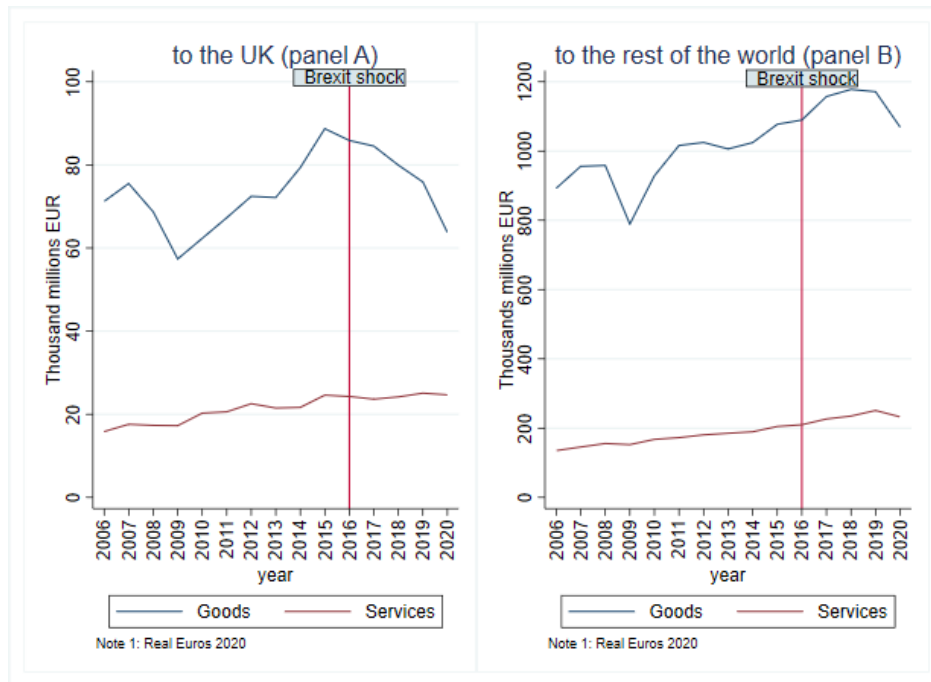


Figure 5 looks more into sectoral heterogeneity in the Brexit response. Using data at the industry level, it plots the change in the industry's export share to the UK after the Brexit referendum against the level of the export share before the referendum. While there

¹¹Figure 13 in the Appendix shows the equivalent picture for imports from the UK to Germany. There is no clear impact of Brexit visible, hence we focus on exports in the rest of the paper.

is substantial heterogeneity, we see that, on average, industries with higher export shares pre-referendum also experience the largest declines in their export share after the Brexit referendum.

Figure 5: Sectoral heterogeneity in the Brexit response.

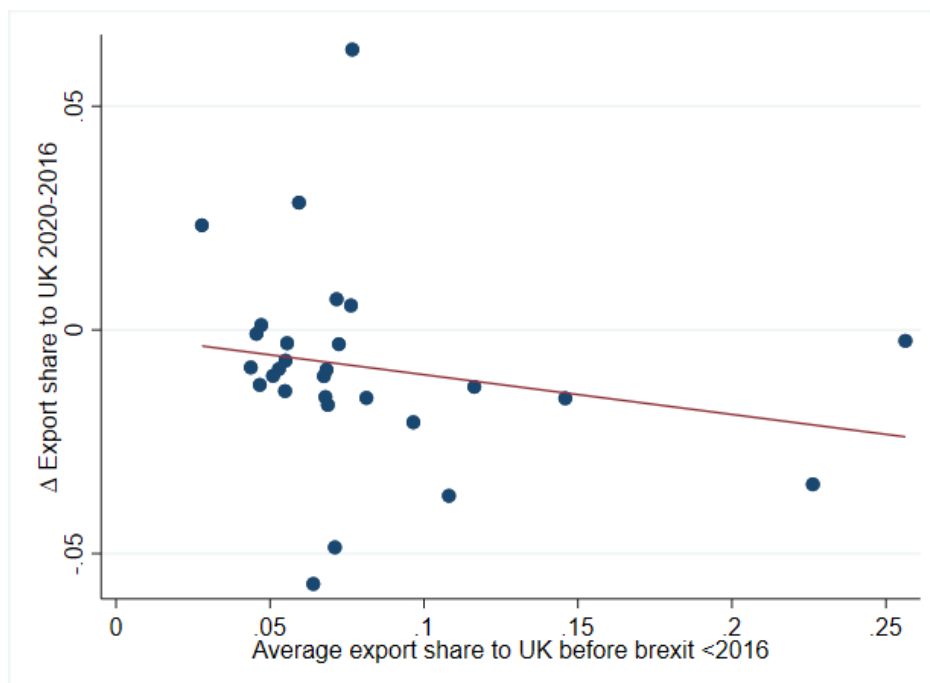


Table 2 digs deeper into the sectoral dimension and illustrates that i) basic pharmaceutical products and pharmaceutical preparations, ii) motor vehicles, trailers and semitrailers, and iii) computer, electronic, and optical products, are the goods exports most affected by the referendum, with the highest declines in their export share to the UK between 2020 and 2016. In terms of services, i) construction, ii) wholesale and retail trade, and iii) technical, trade-related, and other business, are most severely hit.¹²

To look at the impact of the Brexit referendum on exports more systematically, we use the industry level data to more formally model the impact of the referendum on exports of goods and services with the following diff-in-diff model,

¹²Figures 14 and 15 in the Appendix detail the evolution of the export share for all years between 2006 and 2020 for each manufacturing and services industry.

$$\Delta \ln(\exp_{s,t}) = \beta_0 + \beta_1 \text{Exp_UK}_s * \text{Post_Brexit}_t + \delta_s + \delta_t + \epsilon_{s,t} \quad (1)$$

The dependent variable is the change in export value (calculated as the log difference) between t and $t-3$.¹³ We consider total exports, as well as exports to the UK as alternatives. On the right hand side, Exp_UK_s measures the average export share to the UK in relation to total exports of industry s before the Brexit referendum (pre 2016). Post_Brexit_t denotes the post-Brexit referendum time period, which takes a value of 1 for years from 2016 onward and 0 otherwise. The interaction of these two variables thus is the treatment (similar to Liu and Ma, 2020), and the coefficient indicates changes in exports growth rates after the Brexit-referendum depending on pre-referendum export exposure to the UK. The model is estimated separately for services and goods exports.

Results in Table 3 show for both services and goods exports to the UK a significant negative impact of the Brexit-referendum (columns 3 and 4), in line with studies such as Fernandes and Winters (2021) or Graziano et al. (2021). Interestingly, however, we find that total exports of goods are not impacted, while total services exports are negatively affected. This may indicate some readjustment of goods exports, which we will turn to further below. This differential impact on export performance motivates our research question, where we aim to see whether executives in services firms are affected differently from goods exporters in terms of their compensation packages.

3 Empirical estimation

3.1 Baseline results

Recall that the aim of the paper is to examine the link between the Brexit referendum in 2016 and executive compensation. To do so we (as in equation 1) exploit the fact that

¹³We use a three-year growth rate to smooth out any short-term fluctuations in trade, which we see in some individual services and goods sectors, see Appendix Figure 14 and 15.

industries that had a higher export exposure to the UK pre-Brexit are likely to be more strongly affected than others, as shown in Figure 5 above. This allows us to implement a difference-in-differences methodology similar in spirit to Liu & Ma, (2020) and Pierce & Schott (2016). We essentially compare executive compensation of firms in industries that were highly exposed to the UK market pre-referendum (the treatment group) relative to industries with less exposure (the control group), before and after the 2016 Brexit referendum. This cross-sectional variation in pre-Brexit export exposure is arguably exogenous to current developments in executive pay.

Equation 2 shows the baseline diff-in-diff specification:

$$\ln(w_{i,f,s,t}) = \beta_0 + \beta_1 \text{Exp_UK}_s * \text{Post_Brexit}_t + \Gamma X_{f,s,t-1} + \delta_{i,f} + \delta_t + \epsilon_{i,f,s,t} \quad (2)$$

where i denotes executive, f firm, s industry, t year. The dependent variable $\ln(w)$ denotes the log of executive i 's compensation. Exp_UK_s measures the average export share to the UK in relation to total exports of industry s before the Brexit referendum (pre 2016).¹⁴ Post_Brexit_t denotes the post-Brexit referendum time period, which takes a value of 1 for years from 2016 onward and 0 otherwise. In the absence of firm level trade data, export exposure is measured at the industry level as in equation (1). This may not be too problematic for our purposes, since the German "Act of Appropriateness" suggests that compensation should follow industry trends (Beck et al., 2020). Hence, industry-level export exposure, rather than the value for the individual firm, may be particularly important for executive compensation.

X covers covariates at firm level: log total assets, leverage, CAPEX, and return (ROA) rates relative to assets. The δ s capture fixed effects for each executive-firm pair (if) and time (t). The firm-executive fixed effect implies that identification comes only from within-pair changes over time. Any executive-firm pair specific time-invariant unobservables (e.g., standing of the executive in the firm) are hence controlled for. Robust standard errors are

¹⁴Results are robust when export share is measured relative to production, see below.

clustered at industry-year level. In this specification, $\hat{\beta}_1$ in equation 2 represents the effect of Brexit on executive compensation.

The richness of our compensation data allow us to use alternative variables as dependent variable w that capture different aspects of the compensation package: total compensation, fixed compensation, variable compensation, as well as different components of variable compensation (one-year bonus, multi-year bonus, and total equity). Furthermore, given that the compensation data is linked to firm level data, we can also calculate the CEO-to-average-worker pay ratio, which we use in an extension to our baseline model.

Equation 2 with the (log) value of total, variable and fixed compensation as alternative dependent variables is estimated using a fixed effects estimator. The results are presented in Table 4.¹⁵ We estimate the model firstly for all firms, and then separately for manufacturing and services firms. Results show that this is important: while results in column (1), (4) and (7) show that there is an effect of the Brexit referendum on the variable compensation of executives (but not on the fixed component of pay), columns (5) and (6) show that this is entirely driven by services firms. This impact on variable pay is also reflected in lower overall compensation (column 2). Hence, executives in services sector firms are negatively affected by the referendum, while we do not find any evidence that their counterparts in manufacturing firms experience any effect.

The coefficient on the DID term is not only statistically significant in column (2), but the implied magnitude is also economically meaningful: a 0.5 decrease in the export share to UK, which is the difference of the average export share to UK before (11.74) and after the Brexit referendum (11.24) in the services sector, accounts for 7.6% of the decline in total executive compensation in the services sector between 2016 and 2020 (post referendum).¹⁶

¹⁵In a recent paper, Ciccia et al. (2024) establish that the standard two-way fixed effects estimator – as used here – is consistent if: i) the groups receiving large and low treatment ‘doses’ would not have experienced systematically different outcome trends in the absence of treatment (*parallel trend*), ii) the effect is linear and iii) the design contains quasi-stayers (groups whose treatment doses are very low). In Appendix A we look at these requirements and provide evidence suggesting that these conditions are met in our analysis.

¹⁶This is calculated as $0.076 = 0.5 * (\exp(-0.01) - 1) / -0.065$, where -0.065 is the total change in total compensation between 2016 - 2020 from our raw data.

Looking more closely at the variable component, and taking the point estimate from column (5) at face value in this case suggests that the decline in services exports to the UK after the Brexit referendum accounted for 17.4% of the decline in variable executive compensation in the services sector between 2016 and 2020¹⁷. The fact that only the variable component is affected is not surprising. By its very nature, this is the part of compensation that can be easily adjusted in the short-term.

In our data we can also distinguish different components of variable compensation: one-year bonuses, multi-year bonuses, and equity stock and options. However, the values for each of these variable compensation components contain high shares of zeros, as not all executives receive all types of compensation. In order to take this into account, we estimate the models using the values as dependent variable using Poisson pseudo-maximum likelihood (PPML), and we also estimate the probability of receiving each type of variable compensation based on a binary outcome variable. In other words, we distinguish the intensive and extensive margin for these different components of variable compensation.

The respective estimation results for the values and the probability are reported in Table 5 and Table 6. Results in Table 5 illustrate that the negative Brexit effect on the value of variable compensation in the services sector is driven by a fall in one-year (column 2) and multi-year (column 5) bonuses, while it did not impact on equity. Table 6 additionally shows that executives in services firms also experienced a reduction in the probability of receiving a multi-year bonus as a result of the Brexit referendum. Hence, for services firms, the adjustment in terms of variable compensation for executives happened at both the intensive and extensive margins.

Interestingly, even though we did not find any effects on aggregate compensation of executives in manufacturing firms we now see a re-adjustment in terms of components of variable pay. In particular, columns (6) and (9) in Table 5 show that the value of multi-year bonuses was impacted negatively, while the value of equity compensation increased as a

¹⁷Calculated as $0.174 = 0.5 * (\exp(-0.029) - 1) / -0.082$

result of the Brexit referendum. In fact, equity payments were also affected at the extensive margin for manufacturing executives (Table 6) where we find that they are more likely to receive one in the aftermath of the referendum.

3.2 Robustness

Before we move on to consider mechanisms and extensions, we attempt to establish the robustness of our baseline results to different alternative specifications. In our baseline model (equation 2) the exposure of the firm to the UK pre-referendum is measured as exports to the UK relative to total exports. In a first robustness check we use as alternative definition the share of exports to the UK relative to total production.¹⁸ This captures the importance of trade with the UK relative to total overall size of the firm, rather than just export performance. Results, which are reported in Tables 13 to 15 in the Appendix are reassuringly similar to the baseline results reported above.

As we discussed above, our panel of DAX and MDAX firms is somewhat unbalanced. While we have information on 78 firms over 15 years, on average, each firm appears only 8 years in the sample. Only 34 firms have observations for all sample years. In order to check whether the unbalanced nature of our sample impacts our results, we restrict our estimation to the balanced sample of 34 firms. This does not affect results, which are robust to this change. Estimation results for this, as for all other robustness checks below, are not reported here to save space but can be obtained from the authors upon request.

Our data spans the period 2006 to 2020. The last year marks the beginning of the Covid pandemic which had severe implications for the world economy. In order to make sure that this does not bias our results, we conduct another robustness check where the year 2020 is omitted from the estimation sample. Again, results are very similar to the baseline.

The baseline model in equation (2) includes executive-firm pair fixed effects to control for any pair specific time invariant unobservables. In a more general set-up we now include

¹⁸Table 12 in the Appendix shows descriptive statistics by industry of the exports to UK relative to total production.

instead executive and firm fixed effects separately, which allows us to keep the executive identity in case they change firms. Results are again robust.

As we discuss above, the focus of this paper is clearly on export activity and how this relates to executive compensation. However, imports may of course also change, and this may impact on compensation as well. In order to exclude this possibility, we include the sectoral share of imports from UK as an additional covariate in order to control for the potential Brexit effect via imports. This is done using the contemporaneous share, or the one-year lag. Results are again robust to this change.

3.3 Potential mechanisms

Thus far, our overall results suggest that, while there appears to be some reallocation across payment components for manufacturing executives, their overall compensation levels appear unaffected by the Brexit referendum. Not so for executives in services firms who, on average, experience decreases overall, in particular due to reduced payments through bonuses. Why this difference between manufacturing and services firms? Does it merely reflect that services executives are hit by "bad luck" (Garvey & Milbourn, 2006; Bertrand & Mullainathan, 2001) or is there some other reason?

If executive pay is tied to firm-specific performance (Ma & Ruzic, 2020) then the difference between manufacturing and services firms should reflect some differences in the impact of the Brexit referendum on performance in these two broad sectors. As we showed in Figure 4 above, both services and goods exports to the UK experienced a decline after the Brexit referendum. But only services sectors saw an overall decline in total exports as a result. This suggests that goods exports from the UK were successfully redirected to other destinations, while this may not have been the case for services exports. In order to see whether this might have been the case, we present in Table 7 results from estimations of equation 1 (at the industry level), where the dependent variable is the change of the log of total exports to other trade partners: the US, other EU countries, China, and EFTA countries.

The results are illuminating. We find that goods trade with the rest of the EU increased significantly after the Brexit referendum, while trade with other major partners declined. Hence, German exporters of manufacturing goods were able to readjust their export portfolio as a result of the Brexit-referendum, focusing more on the nearby EU market. This possibly alleviated any potential negative impact due to the decline in exports to the UK. Services exporters were not able to do so. We do not find any statistically significant positive effect in any of the markets; in fact, we find a slight decrease in exports to the US and to EFTA countries as a result of the referendum. Hence, services firms do not appear to have been able to divert exports – possibly reflecting higher barriers to trade in services (see WTO, 2019; Bernasconi et al., 2025; Fernandez et al., 2022) – and were, thus, hit fully by the drop in exports to the UK.

Using the firm level dimension of our data we can also see how the Brexit referendum affected overall sales of a firm. To do so we estimate a model similar to equation (2) with the dependent variable defined as firm level sales. Results in Table 8 show a negative, but statistically insignificant coefficient for firms in services sectors. Taken together with the findings on export performance this suggests that, while services exporters experienced declines in overall exports, this did not lead to reductions in overall sales, at least in the short run. The negative impact on executive compensation may thus reflect a "punishment" for lost exports rather than for overall sales.

Table 2: German export share to UK relative to total exports, 2006, 2016, and 2020

Sector	Description	Shares			$\Delta\%$	
		2006	2016	2020	20-06	20-16
Goods	Basic pharmaceutical products and pharmaceutical preparations	5.0	8.9	4.1	-18.7	-54.5
Services	Construction	7.7	13.0	7.3	-5.3	-43.6
Goods	Motor vehicles, trailers and semi-trailers	10.7	11.8	8.1	-23.8	-31.3
Goods	Computer, electronic and optical products	8.9	5.9	4.4	-50.6	-25.5
Goods	Fabricated metal products, except machinery and equipment	6.0	5.9	4.6	-23.9	-23.1
Services	Wholesale and retail trade	7.4	7.3	5.6	-23.9	-22.9
Goods	Textiles, wearing apparel, and leather products	4.9	5.8	4.6	-6.5	-21.1
Services	Technical, Trade-related and other business services	10.6	10.0	7.9	-25.3	-20.7
Goods	Paper products	9.1	7.4	5.9	-35.2	-20.5
Goods	Machinery and equipment n.e.c.	5.3	5.4	4.3	-18.4	-19.2
Goods	Electrical equipment	5.0	4.6	3.8	-24.5	-18.3
Goods	Rubber and plastic products	7.6	6.6	5.6	-26.9	-15.6
Services	Insurance and pension	5.3	22.6	19.2	261.6	-15.3
Goods	Other non-metallic mineral products	5.8	5.7	4.9	-16.5	-15.2
Goods	Furniture and other manufacturing	6.7	7.0	6.1	-8.9	-12.8
Goods	Chemicals and chemical products	6.1	5.4	4.7	-22.6	-12.8
Services	Professional and management consulting services	16.0	12.8	11.2	-29.6	-12.0
Services	Telecommunication, computer and information services	10.1	13.7	12.4	23.0	-9.3
Goods	Wood and of products of wood and cork, except furniture	6.1	6.0	5.7	-7.0	-5.0
Goods	Food, beverages and tobacco products	7.4	7.2	6.8	-8.2	-4.5
Goods	Coke and refined petroleum products	7.0	2.5	2.4	-65.4	-3.5
Services	Financial	33.9	21.2	21.0	-38.1	-1.2
Services	Research and development services	4.9	5.1	5.2	6.5	2.1
Goods	Basic metals	6.6	8.4	9.1	38.8	8.2
Services	Transport	8.5	4.9	5.4	-36.6	11.2
Goods	Other transport equipment	10.1	5.8	8.7	-13.9	48.7
Services	Personal, cultural and recreational services	5.2	11.8	18.1	245.3	53.0
Goods	Printing and reproduction of recorded media	4.3	3.8	6.1	42.1	61.4
Simple averages, pre and post Brexit						
	Sector		2006-2015	2016-2020	Δ	$\Delta\%$
	Services		11.7	11.2	-0.5	-4.2
	Goods		6.1	5.8	-0.3	-4.4

Table 3: Impact of the Brexit referendum on exports' growth rate

VARIABLES	(1) $\Delta_3 \ln(Exp_Total)$	(2) $\Delta_3 \ln(Exp_Total)$	(3) $\Delta_3 \ln(Exp_UK)$	(4) $\Delta_3 \ln(Exp_UK)$
Sample	Services	Goods	Services	Goods
Avg_sh_UK(<2016)*	-0.0142*	0.0169	-0.0306***	-0.0370**
Brexit dummy(t>=2016)	(0.00743)	(0.0136)	(0.0113)	(0.0179)
FE	Industry, year			
Observations	120	216	119	216
R-squared	0.412	0.479	0.401	0.466
Dep var mean	0.12	0.03	0.13	-0.01

Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Brexit shock impact on executive compensation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\ln(Total_Comp)_{f,i,s,t}$			$\ln(Variable_comp)_{f,i,s,t}$			$\ln(Fixed_comp)_{f,i,s,t}$		
Sample	Total	Services	Goods	Total	Services	Goods	Total	Services	Goods
Avg_sh_exp_UK(<2016)	-0.002	-0.011*	-0.008	-0.011*	-0.03***	-0.017	0.005	0.002	0.006
*D_Brexit($t \geq 2016$) _{s,t}	(0.005)	(0.005)	(0.024)	(0.006)	(0.006)	(0.026)	(0.003)	(0.003)	(0.023)
X	[Log total assets, leverage rate, CAPEX rate, ROA], t-1								
FE	Executive-firm, year								
Observations	5,357	2,695	2,662	5,058	2,480	2,578	5,357	2,695	2,662
Dep var mean	14.4	14.3	14.4	13.9	13.8	14.0	13.4	13.4	13.4

Robust standard errors clustered at industry-year in parentheses. Sh_exp_UK=Exports to UK/Total exports.

*** p<0.01, ** p<0.05, * p<0.1

Table 5: Brexit shock impact on variable executive compensation - PPML estimation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	<i>One_year_bonus_{f,i,s,t}</i>			<i>Multi_year_bonus_{f,i,s,t}</i>			<i>Equity_{f,i,s,t}</i>		
Sample	Total	Services	Goods	Total	Services	Goods	Total	Services	Goods
Avg_sh_exp_UK(<2016)	-0.003	-0.016**	-0.044	-0.07***	-0.09***	-0.176**	0.007	-0.010	0.063***
*D_Brexit($t \geq 2016$) _{s,t}	(0.006)	(0.007)	(0.030)	(0.015)	(0.011)	(0.069)	(0.006)	(0.007)	(0.016)
X	[Log total assets, leverage rate, CAPEX rate, ROA], t-1								
FE	Executive-firm, year								
Observations	4,888	2,379	2,509	3,318	1,616	1,702	4,235	2,120	2,115
Dep var mean	716,944	649,834	780,577	490,798	331,268	642,267	696,094	755,401	636,648

Robust standard errors clustered at industry-year in parentheses. Sh_exp_UK=Exports to UK/Total exports.

Singleton observations are dropped iteratively.

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Brexit shock impact on probability to receive variable compensation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$D(One_year_bonus = 1)_{f,s,t}$			$D(Multi_year_bonus = 1)_{f,s,t}$			$D(Equity = 1)_{f,s,t}$		
Sample	Total	Services	Goods	Total	Services	Goods	Total	Services	Goods
Avg_sh_exp_UK(<2016)	-0.002	-0.004	0.010	-0.010	-0.014**	-0.006	-0.002	-0.003	0.038***
*D_Brexit($t \geq 2016$) _{s,t}	(0.003)	(0.004)	(0.008)	(0.006)	(0.006)	(0.024)	(0.003)	(0.004)	(0.013)
X	[Log total assets, leverage rate, CAPEX rate, ROA], t-1								
FE	Executive-firm, year								
Observations	5,058	2,480	2,578	5,058	2,480	2,578	5,058	2,480	2,578
Dep var mean	0.89	0.90	0.88	0.42	0.41	0.43	0.73	0.77	0.69

Robust standard errors clustered at industry-year in parentheses. Sh_exp_UK=Exports to UK/Total exports.

*** p<0.01, ** p<0.05, * p<0.1

Table 7: Brexit referendum impact on exports' growth rates to other destination

VARIABLES	(1) $\Delta_3 \ln(Exp_US)$	(2) $\Delta_3 \ln(Exp_US)$	(3) $\Delta_3 \ln(Exp_EU27^1)$	(4) $\Delta_3 \ln(Exp_EU27^1)$	(5) $\Delta_3 \ln(Exp_China)$	(6) $\Delta_3 \ln(Exp_China)$	(7) $\Delta_3 \ln(Exp_EFTA^2)$	(8) $\Delta_3 \ln(Exp_EFTA^2)$
Sample	Services	Goods	Services	Goods	Services	Goods	Services	Goods
Avg_sh_UK(<2016)	-0.0179	-0.0455*	-0.0120	0.0524***	-0.0285	-0.0342*	-0.0548	-0.0428***
*Brexit dummy($t \geq 2016$)	(0.0147)	(0.0235)	(0.0103)	(0.0178)	(0.0229)	(0.0181)	(0.0543)	(0.0127)
FE	Industry, year							
Observations	119	216	120	216	119	216	120	216
R-squared	0.326	0.468	0.292	0.346	0.318	0.605	0.377	0.461
Dep var mean	0.14	0.04	0.08	0.01	0.31	0.30	0.02	0.05

Robust standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

¹ EU27: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden. (Germany is the exporter).

² EFTA: Iceland, Norway, Liechtenstein, Switzerland.

Table 8: Brexit shock impact on sales

Variables	(1)	(2) $\ln(net_sales)_{f,s,t}$	(3)
Sample	Total	Services	Goods
Avg_sh_exp_UK(<2016)	0.000	-0.001	0.014**
*D_Brexit($t \geq 2016$) _{s,t}	(0.003)	(0.004)	(0.006)
X	[Log total assets, leverage rate, CAPEX rate, ROA], t-1		
FE	Firm, year		
Observations	1,051	515	536
Dep var mean	22.7	22.52	22.87

Robust standard errors clustered at industry-year in parentheses.

Sh_exp_UK=Exports to UK/Total exports.

*** p<0.01, ** p<0.05, * p<0.1

4 Extensions

An extension to our analysis considers the role of corporate governance structures, which may have an impact on executive compensation (Choi et al., 2024). Most German firms implement a two-tier board structure in which executives and directors are separated organizationally (Andres et al., 2014), contrasting with the American one-tier system.¹⁹ However, there is an exception to this two-tier board rule that allows us to exploit econometrically some variation in corporate governance: the governance structure of *Societas Europaea* – *SE* companies (which account for 18% of the sample) allows flexibility in the board system, and the two-tier system is not mandatory.

Table 9 shows estimations considering variable compensation separately for *Societas Europaea* – *SE* firms and the rest of the companies. The results, which relate to services firms only, indicate that the Brexit referendum impacted variable compensation in the services

¹⁹See Block and Gerstner (2016) for a comparison between the United States (one-tier) and Germany (two-tier) board structure.

sector in a similar magnitude independently of the firm governance structure (-0.031 statistically significant at 1% for services firms with non-mandated two-tier boards and -0.028 statistically significant at 1% for services firms with mandatory two-tier boards). This suggests that the baseline results described above are robust to the inclusion of corporate governance.²⁰

Finally, we look at what happened to the average worker in the firm compared to the executives. Table 10 shows estimates where we firstly look at the average wage at the firm level (columns 1 to 3). This shows that, similar to executive pay, employees in services sector firms also experienced a negative impact on wages due to the Brexit referendum. How did the effect on the average worker compare to that on CEOs? To answer this question we then consider the CEO-to-worker pay ratio as dependent variable, as in Ma and Ruzic (2020). They show that globalization (in their case measured by exports to China) increased this pay ratio, and thus, fostered inequality.

Our regressions in Table 10 show that the Brexit referendum also had a statistically significant and positive effect on the CEO-to-worker pay ratio but only for firms in the services sectors. This increase in the CEO-to-worker pay ratio suggests that the negative Brexit effect on average wages was proportionally higher than its negative effect on executive compensation. This, thus, raises the pay gap vis-a-vis the average worker in the service firm, increasing inequality. Hence, while Ma and Ruzic (2020) show that positive trade shocks can increase inequality, we find that this is also the case for a negative shock to economic integration at least in the services sector. In contrast, neither workers nor executives in the manufacturing sector were affected in their remuneration due to Brexit, keeping the CEO-to-worker pay ratio intact.

Finally, Table 11 shows estimates considering the CEO-to-worker pay ratio separately for *Societas Europaea* – *SE* firms (non-mandatory two-tier) and the rest of the companies.

²⁰In addition, the baseline model in equation 2 already includes executive-firm invariant characteristics and, since corporate governance structures vary slowly across time in Germany (Beck et al., 2020), controls for some differences in corporate governance.

The results, which relate to services firms only, show that the Brexit referendum fostered the inequality in the *Societas Europaea* – *SE* firms, while there was no effect in two-tier firms. These findings suggest that some characteristics of the two-tier board structure, such as the representation of employees on the supervisory board and the separate board that monitors executive actions, may contribute to firms taking into account equality criteria when they adapt to an exogenous adverse shock.²¹

Table 9: Brexit shock impact on variable executive compensation in the services sector disaggregated by board structure

Variables	(1)	(2) $\ln(Variable_comp)_{f,s,t}$
Sample	<i>Societas Europaea</i> firms ¹	Two-tier firms
Avg_sh_UK(<2016)	-0.031***	-0.028***
*D_Brexit(t>=2016)	(0.011)	(0.007)
Observations	773	1,707
Dep var mean	14.10	13.70
X	[Log total assets, leverage rate, CAPEX rate, ROA], t-1	
FE	Executive-firm, year	

Robust standard errors clustered at industry-year in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Sh_exp_UK=Exports to UK/Total exports.

¹The two-tier board system is not mandatory for the *Societas Europaea* – *SE* firms.

²¹Expanding the scope of these results, the differences in the board structure in Germany, where the average firm implements the two-tier system, and US, where the one-tier system prevails, could be one of the reasons why US has a higher Gini and income share of the top 1 percent than Germany.

Table 10: Brexit shock impact on average wage and CEO-to-worker pay ratio

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		$\ln(avg_wage)_{f,s,t}$		$\ln(CEO(max)_pay_ratio)_{f,s,t}$ ¹			$\ln(CEO(avg)_pay_ratio)_{f,s,t}$ ²		
Sample	Total	Services	Goods	Total	Services	Goods	Total	Services	Goods
Avg_sh_UK(<2016)	-0.01***	-0.013**	0.004	0.0167**	0.0141**	-0.0218	0.0169***	0.0114*	-0.00518
*D_Brexit(t>=2016) _{s,t}	(0.004)	(0.005)	(0.007)	(0.00461)	(0.00610)	(0.0243)	(0.00476)	(0.00624)	(0.0260)
X	[Log total assets, leverage rate, CAPEX rate, ROA], t-1								
FE	Firm, year								
Observations	929	475	454	929	475	454	929	475	454
Dep var mean	11.07	11.10	11.03	3.77	3.67	3.87	3.32	3.21	3.42

Robust standard errors clustered at industry-year in parentheses. Sh.exp_UK=Exports to UK/Total exports.

*** p<0.01, ** p<0.05, * p<0.1

¹ Total compensation of the top earner executive/average wage.

² Average compensation of the executives/average wage.

Table 11: Brexit shock impact on CEO-to-worker pay ratio in the services sector disaggregated by board structure

Variables	(1)	(2) $\ln(CEO(avg)\text{-}pay_ratio)_{f,s,t}$ ¹
Sample	<i>Societas Europaea</i> firms ²	Two-tier firms
Avg_sh_UK(<2016)	0.030**	0.005
*D_Brexit(t>=2016)	(0.014)	(0.007)
Observations	134	341
Dep var mean	3.449	3.122
X	[Log total assets, leverage rate, CAPEX rate, ROA], t-1	
FE	Firm, year	

Robust standard errors clustered at industry-year in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Sh_exp_UK=Exports to UK/Total exports.

¹ Average compensation of the executives/average wage.

² The two-tier board system is not mandatory for the *Societas Europaea* – *SE* firms.

5 Conclusion

This paper looks at the impact of an announcement of an adverse trade shock (Brexit referendum) on executive compensation for German companies listed in the DAX and MDAX stock indices. We analyse data for the 2006-2020 period through a difference-in-differences specification. In particular, we look at heterogeneous effects of the Brexit referendum on executives in firms in services and manufacturing sectors.

The main finding is that the referendum impacted negatively the compensation of executives in the services sector. These results are not only statistically significant but also economically meaningful. We show that they are driven by a fall in the variable part of compensation (bonuses), rather than the fixed components. In contrast, executive compensation in the manufacturing sector was not affected (although there was a replacement of bonuses by equity).

Looking at mechanisms, our evidence suggests that executives in the manufacturing sector may have successfully redirected exports from the UK to other countries (in particular the EU), and they were able to maintain or even increase overall output levels. By contrast, services firms experienced reductions in overall exports and failed to readjust their export destination portfolio. This may potentially be due to higher regulations and other trade costs in services industry which makes switching export markets more difficult (WTO, 2019; Bernasconi et al., 2025).

We also find that the Brexit referendum led to an increase in the CEO-to-worker pay ratio in the services sector, while this was not the case in manufacturing. Brexit thus implied a proportionally higher reduction in wages for the average workers than in executive compensation for services firms, raising the CEO-to-worker pay ratio. While Ma and Ruzic (2020) show that positive trade shocks can foster inequality, our result implies that negative shocks to globalization can also do so.

Overall, this is the first paper that we are aware of that looks at the implications of a

negative shock to trade integration on executive compensation and firm performance. Given the current geopolitical situation, more of such "natural experiments" are - unfortunately - likely to be generated in the years to come.

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7 Appendix

7.1 Appendix A: Differences-in-differences in heterogeneous adoption designs without stayers

In a recent working paper, Ciccina et al. (2024) analyzes heterogeneous adoption designs without stayers (no group is treated at period one and all groups receive a positive treatment dose in the next period), which describe universal policies, like Brexit, in which all groups are exposed to a different degree to the policy. They constructed new estimators robust to heterogeneous treatment effects, since the ones proposed so far (de Chaisemartin & D’Haultfœuille, 2018, 2020, 2023; Callaway et al., 2024) cannot be implemented in these designs (Ciccina et al., 2024). They also established that the standard two-way fixed effects estimator is consistent if: i) the groups receiving large and low treatment ‘doses’ would not have experienced systematically different outcome trends in the absence of treatment (*parallel trend*), ii) the effect is linear and iii) the design contains quasi-stayers (groups whose treatment doses are very low). These conclusions can be generalizable to applications with several time periods.

One way to partly verify the first requirement is to calculate a pre-tend specification as in Pierce and Schott (2016), in which $Post_Brexit_t$ is replaced by a set of year dummies in the baseline equation.²² For the variation in the dependent variables to be attributable to Brexit, Exp_UK_s should be correlated with executive compensation after Brexit, not before. Figure 6 displays the coefficients of the interaction of Exp_UK_s with the year dummies for variable compensation in the services sector; the coefficients become negative statistically significant since 2016 when Brexit occurred. In the same way, the coefficients of the interaction of Exp_UK_s with the year dummies for the probability to receive equity compensation in

²²

$$\ln(W)_{i,f,s,t} = \beta_0 + \sum_{y=2008}^{2020} \beta_y 1\{y = t\} Exp_UK_s + \Gamma X_{f,s,t-1} + \delta_{i,f} + \delta_t + \epsilon_{f,s,t} \quad (3)$$

the manufacturing sector become positive statistically significant since 2016 when Brexit occurred (figure 10). More generally, the figures 6-12 show the confidence interval of the coefficients of the interaction of Exp_UK_s with the year dummies for all dependent variables. Around 69% of these figures show the expected pattern in accordance with the parallel trend assumption²³, consequently, the results are on average consistent with this assumption.

In order to verify the second requirement, we estimate the Jann (2008) linearity test for $Exp_UK_s * Post_Brexit_t$ in the baseline specification, not the Stute linearity test proposed by Ciccia et al. (2024), since it only works with balanced panel which would reduce 96% the sample (from 5,357 to 195).²⁴ Figures 6-12 show that it is not possible to reject the linearity hypothesis for 59% of the variables (assuming 3 bins). However, further research about linearity is suggested.

Finally, the export share to the UK for 3 sectors is below 5% after 2016, which could constitute the quasi-stayers group.²⁵ In conclusion, the diff-in-diff estimators are likely to be consistent and it is not necessary to estimate the new estimators robust to heterogeneous treatment effects proposed by Ciccia et al. (2024), which would also substantially reduce the estimation sample.

²³For variables that were not significantly affected by Brexit, the confidence intervals for all years should include 0. Conversely, for variables that were significantly affected by Brexit, the confidence intervals for the years 2016–2020 should not include 0.

²⁴An alternative Yatchew linearity test is recommended only with very large datasets.

²⁵There is no a statistical software to calculate the quasi-stayers test proposed by Ciccia et al. (2024).

Figure 6: Timing of the Brexit effect on total and variable compensation

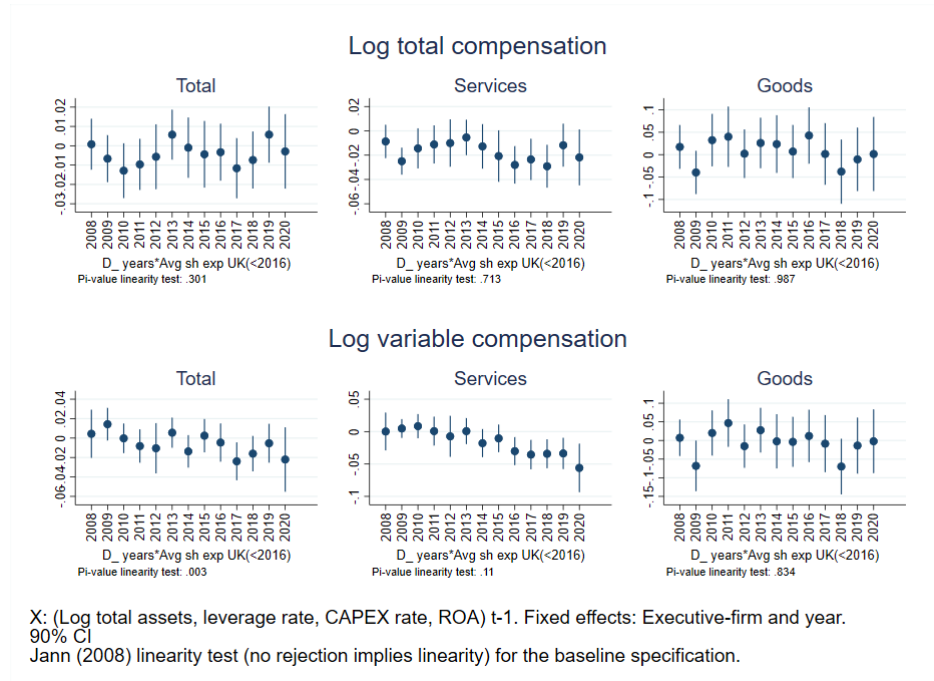


Figure 7: Timing of the Brexit effect on fixed compensation

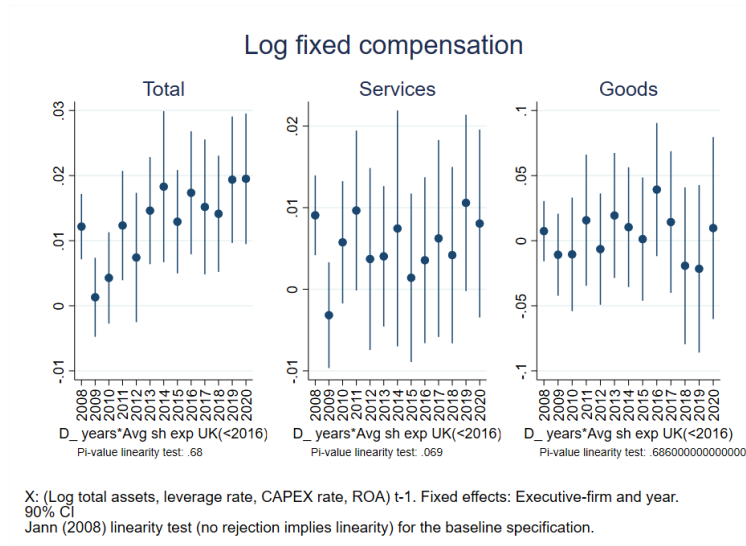


Figure 8: Timing of the Brexit effect on one-year bonus

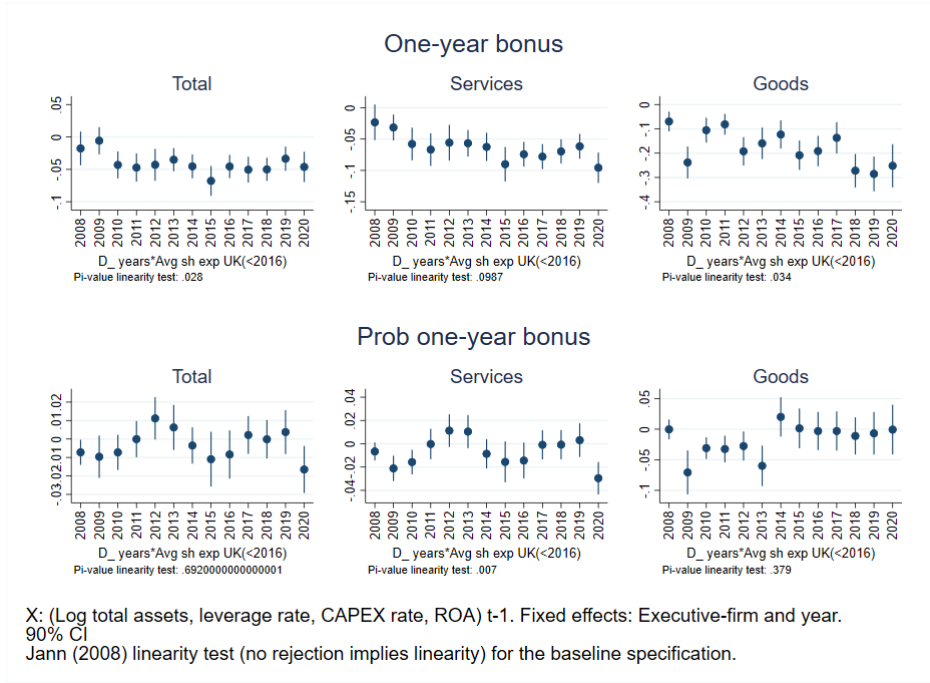


Figure 9: Timing of the Brexit effect on multi-year bonus

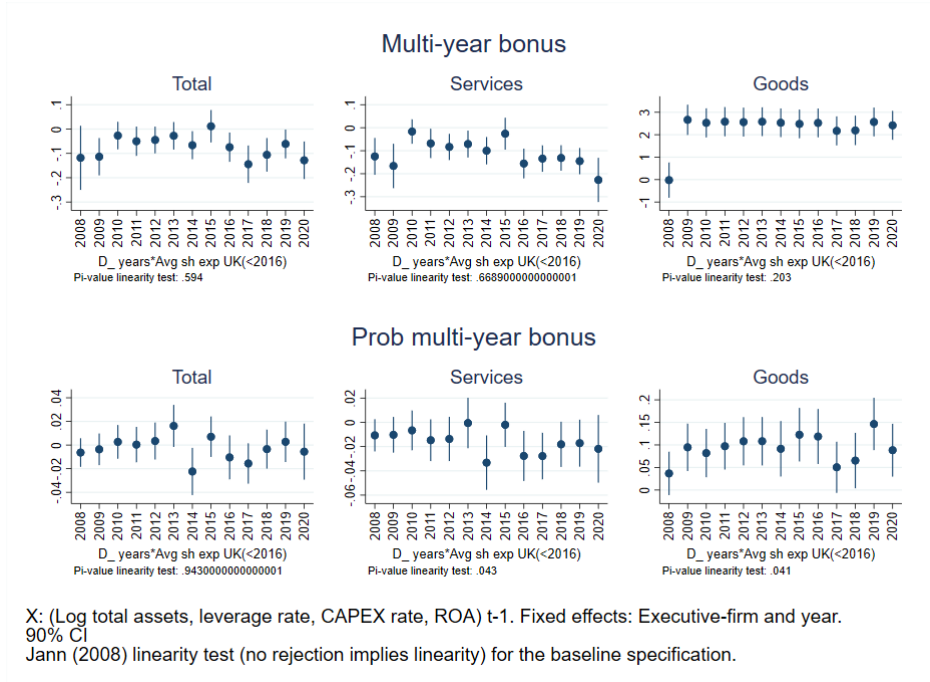


Figure 10: Timing of the Brexit effect on equity

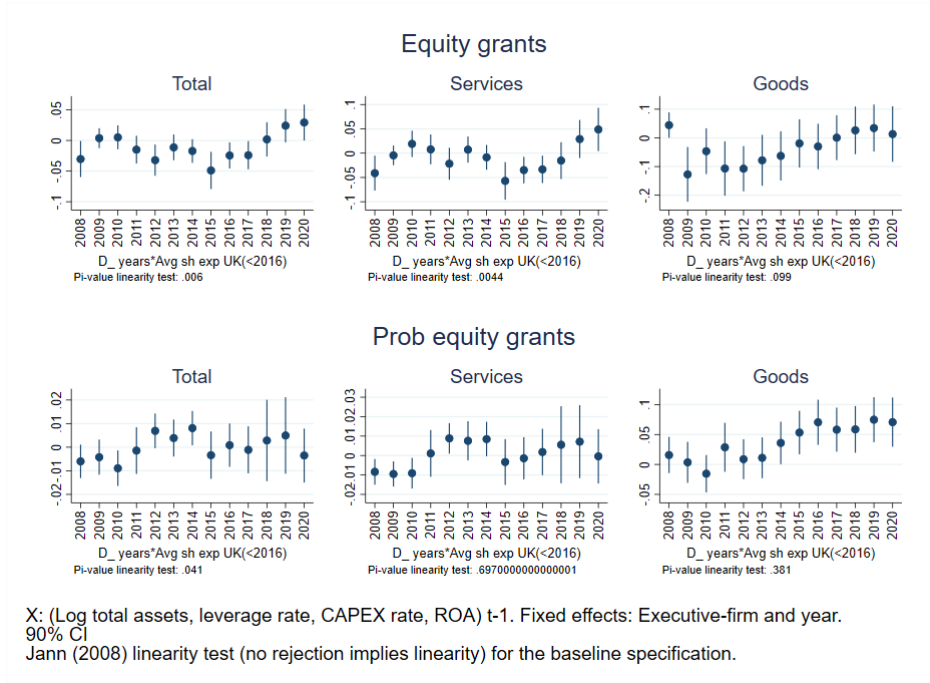


Figure 11: Timing of the Brexit effect on sales and average wage

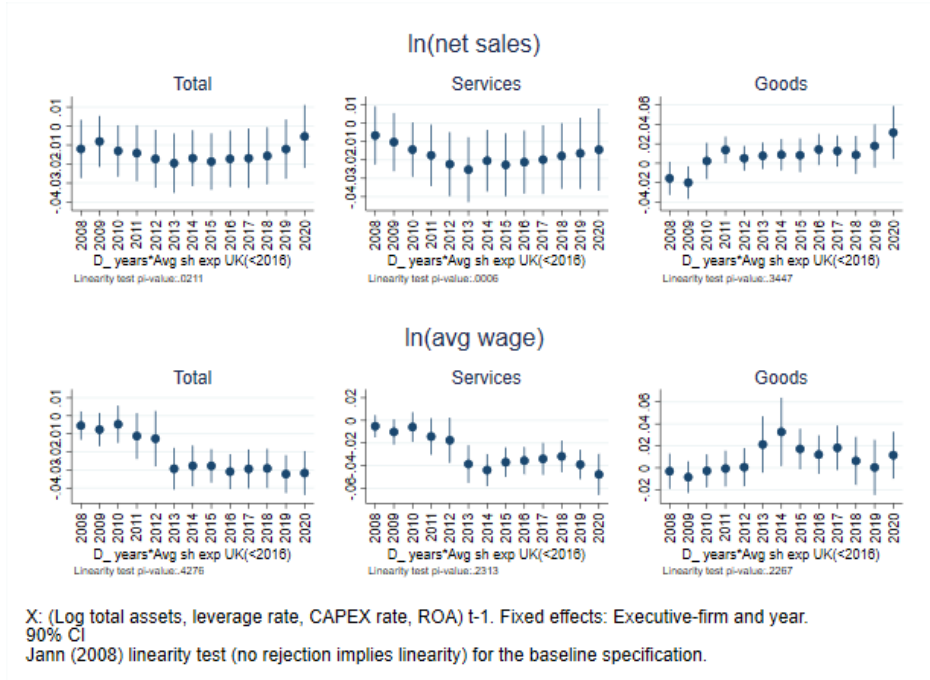
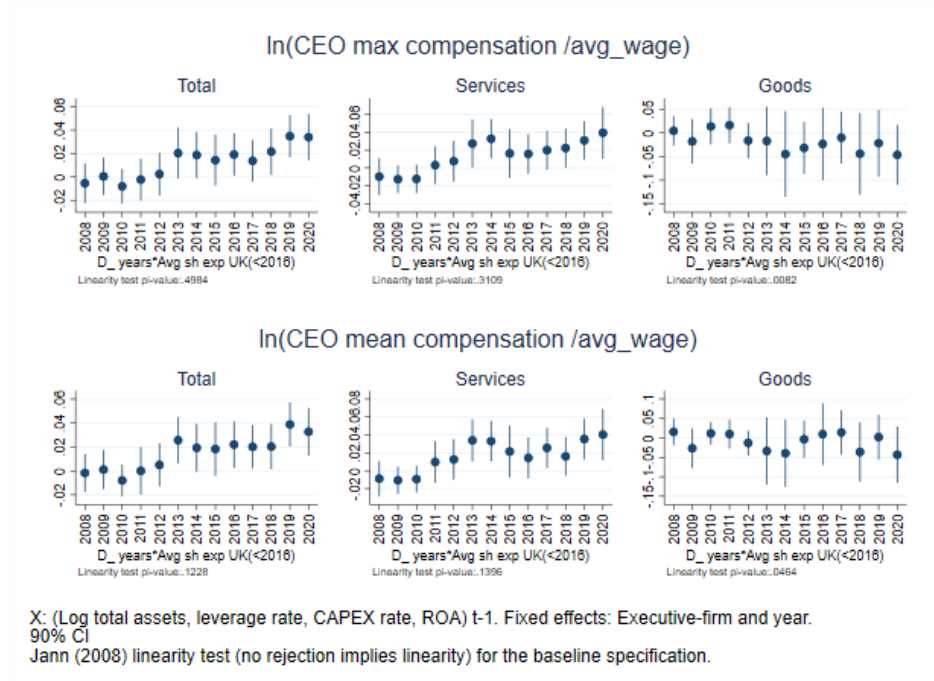


Figure 12: Timing of the Brexit effect on CEO to worker pay ratio



7.2 Appendix B: Additional tables and figures

Figure 13: German imports, 2006-2020.

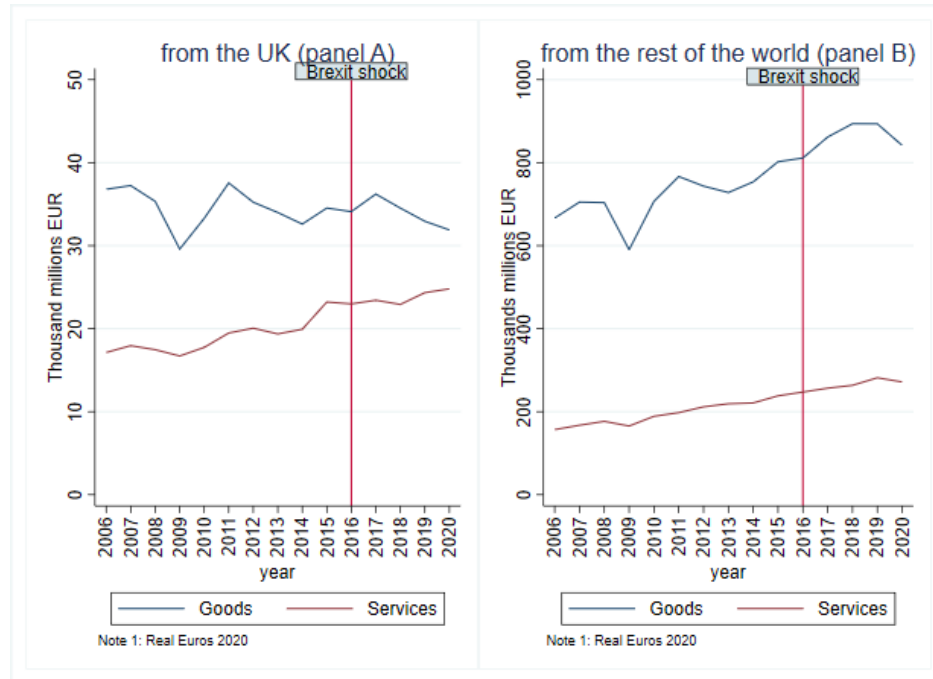
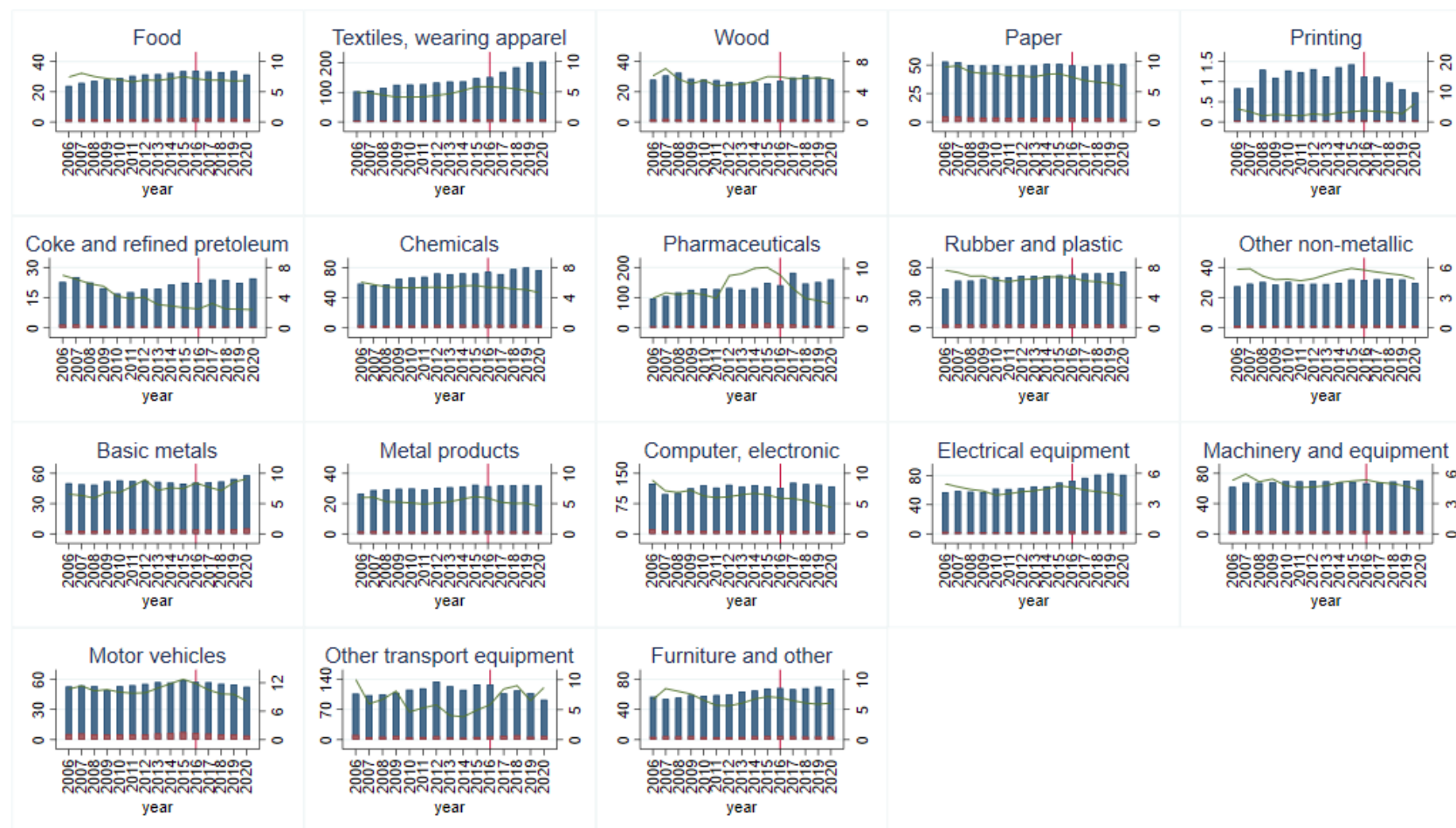


Figure 14: Export share to UK relative to total exports and output by manufacturing industry, 2006-2019. Classification: CPA 2.1



EXP Total (%)



EXP UK (%)

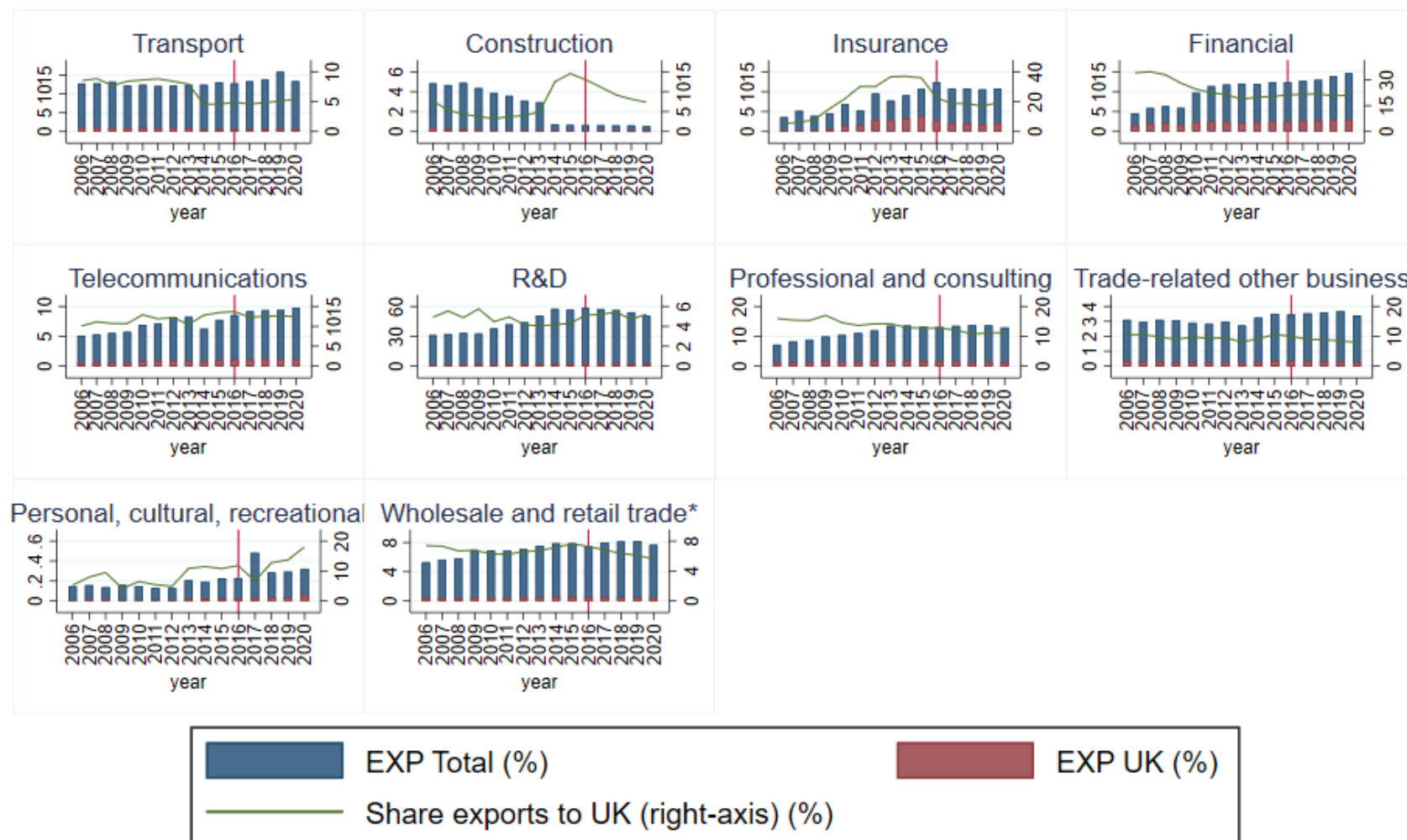


Share exports to UK (right-axis) (%)

EXP Total = [EXP/Output]*100

EXP UK = [EXP to UK /Output]*100

Figure 15: Export share to UK relative to total exports and output by services industry, 2006-2019. Classification: EBOPS 2010



$$\text{EXP Total} = [\text{EXP}/(\text{Output})]*100$$

$$\text{EXP UK} = [\text{EXP to UK} / (\text{Output})]*100$$

$$*\text{Exp wholesale retail} = \text{Exp wholesale retail goods} * (\text{Gross margin} / \text{Turnover})$$

$$*\text{Exp wholesale retail UK} = \text{Exp wholesale retail goods} * (\text{Gross margin} / \text{Turnover}) * \text{Share exp goods to UK.}$$

Source: Eurostat. Authorial calculations.

Table 12: German export share to UK relative to production, 2006, 2016, and 2020

Sector	Description	Shares			$\Delta\%$	
		2006	2016	2020	20-06	20-16
Services	Construction	0.4	0.1	0.0	-89.7	-53.3
Goods	Basic pharmaceutical products and pharmaceutical preparations	4.8	12.6	6.5	34.1	-48.3
Goods	Motor vehicles, trailers and semi-trailers	5.6	6.8	4.3	-24.3	-37.0
Services	Insurance and pension	0.2	2.8	2.1	985.2	-26.1
Goods	Computer, electronic and optical products	11.1	6.7	5.1	-53.5	-23.3
Services	Technical, Trade-related and other business services	0.3	0.3	0.3	-18.3	-22.0
Goods	Fabricated metal products, except machinery and equipment	1.6	1.9	1.5	-8.8	-22.0
Goods	Manufacture of other non-metallic mineral products	1.6	1.8	1.4	-9.7	-20.5
Services	Wholesale and retail trade	0.4	0.5	0.4	10.4	-20.4
Goods	Paper and paper products	4.8	3.7	3.0	-37.9	-18.7
Goods	Machinery and equipment n.e.c.	3.3	3.6	3.1	-7.1	-14.4
Goods	Furniture and other manufacturing	3.8	4.7	4.1	8.2	-13.7
Services	Professional and management consulting services	1.2	1.7	1.5	26.5	-12.6
Services	Research and development services	1.5	3.0	2.6	72.5	-11.9
Goods	Food, beverages and tobacco products	1.8	2.4	2.1	20.8	-11.4
Goods	Chemicals and chemical products	3.6	4.0	3.6	1.2	-10.3
Goods	Rubber and plastic products	3.0	3.5	3.1	4.9	-10.1
Goods	Electrical equipment	2.9	3.4	3.0	6.7	-9.3
Goods	Manufacture of wood and of products of wood and cork	1.7	1.6	1.6	-6.0	-1.5
Services	Telecommunication, computer and information services	0.5	1.2	1.2	135.2	4.0
Goods	Printing and reproduction of recorded media	0.0	0.0	0.0	24.9	5.1
Goods	Coke and refined petroleum products	1.6	0.6	0.6	-62.8	5.8
Goods	Textiles, wearing apparel, and leather products	5.1	8.8	9.4	84.7	6.4
Goods	Other transport equipment	10.8	7.4	8.0	-25.2	8.2
Services	Transport	1.1	0.6	0.7	-33.5	16.2
Services	Financial	1.5	2.6	3.1	98.8	16.9
Goods	Basic metals	3.3	4.3	5.3	60.6	24.0
Services	Personal, cultural and recreational services	0.0	0.0	0.1	659.8	115.1

Table 13: Brexit shock impact on executive compensation for the biggest German firms

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\ln(Total_Comp)_{f,i,s,t}$			$\ln(Variable_comp)_{f,i,s,t}$			$\ln(Fixed_comp)_{f,i,s,t}$		
Sample	Total	Services	Goods	Total	Services	Goods	Total	Services	Goods
Avg_exp_Y_UK(<2016)	-0.019	-0.095*	0.019	-0.034*	-0.29***	0.032	-0.007	0.020	0.006
*D_Brexit($t \geq 2016$) _{s,t}	(0.014)	(0.055)	(0.021)	(0.018)	(0.061)	(0.029)	(0.010)	(0.032)	(0.016)
X	[Log total assets, leverage rate, CAPEX rate, ROA], t-1								
FE	Executive-firm, year								
Observations	5,357	2,695	2,662	5,058	2,480	2,578	5,357	2,695	2,662
Dep var mean	14.37	14.30	14.44	13.91	13.83	13.98	13.38	13.35	13.41

Robust standard errors clustered at industry-year in parentheses. Avg_exp_Y_UK=Exports to UK/Production.

*** p<0.01, ** p<0.05, * p<0.1

Table 14: Brexit shock impact on variable executive compensation - PPML estimation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	<i>One_year_bonus_{f,i,s,t}</i>			<i>Multi_year_bonus_{f,i,s,t}</i>			<i>Equity_{f,i,s,t}</i>		
Sample	Total	Services	Goods	Total	Services	Goods	Total	Services	Goods
Avg_exp_Y_UK(<2016)	-0.05***	-0.19***	-0.029	-0.003	-0.93***	-0.011	-0.020	-0.108	0.071***
*D_Brexit($t \geq 2016$) _{s,t}	(0.019)	(0.063)	(0.026)	(0.048)	(0.149)	(0.063)	(0.016)	(0.077)	(0.026)
X	[Log total assets, leverage rate, CAPEX rate, ROA], t-1								
FE	Executive-firm, year								
Observations	4,888	2,379	2,509	3,318	1,616	1,702	4,235	2,120	2,115
Dep var mean	716,944	649,834	780,577	490,798	331,269	642,267	696,0945	755,401	636,648

Robust standard errors clustered at industry-year in parentheses. Avg_exp_Y_UK=Exports to UK/Production.

Singleton observations are dropped iteratively.

*** p<0.01, ** p<0.05, * p<0.1

Table 15: Brexit shock impact on probability to receive variable compensation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$D(One_year_bonus = 1)_{f,s,t}$			$D(Multi_year_bonus = 1)_{f,s,t}$			$D(Equity = 1)_{f,s,t}$		
Sample	Total	Services	Goods	Total	Services	Goods	Total	Services	Goods
Avg_exp_Y_UK(<2016)	-0.005	-0.038	-0.011	-0.011	-0.102	-0.025	0.015*	-0.061*	0.032**
*D_Brexit($t \geq 2016$) _{s,t}	(0.005)	(0.042)	(0.008)	(0.014)	(0.064)	(0.024)	(0.008)	(0.036)	(0.013)
X	[Log total assets, leverage rate, CAPEX rate, ROA], t-1								
FE	Executive-firm, year								
Observations	5,058	2,480	2,578	5,058	2,480	2,578	5,058	2,480	2,578
Dep var mean	0.89	0.90	0.88	0.42	0.41	0.43	0.73	0.77	0.69

Robust standard errors clustered at industry-year in parentheses. Avg_exp_Y_UK=Exports to UK/Production.

*** p<0.01, ** p<0.05, * p<0.1

7.3 Appendix C: Details on data construction

Industry level data

Table 16: Eurostat datasets and correspondences description

Variables	Dataset name	Industry classification	Coverage years
1. Production and value added	<i>estat_nama_10_a64</i>	NACE Rev 2	2006-2020
2. Trade value in services	<i>estat_bop_its_det</i>	EBOPS 2002	2006-2013
3. Trade value in services	<i>estat_bop_its6_det</i>	EBOPS 2010	2010-2020
4. Trade value in goods	<i>DS-059327</i>	CPA 2.1	2006-2020
5. Exports and imports - whole-sale and retail trade (goods)	<i>estat_ext_tec01</i>	NACE Rev 2	2014-2020
6. Turnover and gross margin - wholesale and retail industry	<i>estat_sbs_na_dt_r2</i>	NACE Rev 2	2008-2020
7. Correspondence table between EBOPS 2002 - EBOPS 2010. See table 17			
8. Correspondence table between NACE Rev 2 - EBOPS 2010. See table 18			

Note: EBOPS: Extended Balance of Payments Services Classification. NACE: Classification of economic activities in the European Union (EU). CPA: Classification of products parallel to that of the NACE at all levels.

In order to homogenize the industrial classification to generate a consistent trade in services panel data between 2006 and 2020, traded values from 2006 to 2009 - which are classified in Extended Balance of Payments Services (EBOPS) 2002 - are converted to EBOPS 2010 based on the concordance shown in table 17.

Originally, the first trade in services dataset is disaggregated at EBOPS 2002 and covers from 2006 to 2013. The second trade in services dataset is disaggregated at EBOPS 2010 and covers from 2010 to 2020. The traded values for the overlapping years (2010-2013) are obtained from the second dataset with the exception of the construction sector, whose values tend to be more realistic in the first dataset. We linearly interpolate missing values. If the missing values were at the initial years, they are replaced by: $X_{t-1} = X_t - \hat{\beta}_1$, in which $\hat{\beta}_1$ is obtained from a simple regression: $X = \beta_0 + \beta_1 \text{Year}$. If the missing values were at the final years, the missing values were replaced by: $X_{t-1} = X_t + \hat{\beta}_1$, in which $\hat{\beta}_1$ is obtained from a simple regression: $X = \beta_0 + \beta_1 \text{Year}$.

In the same way, the services output data, which is classified in NACE Rev 2, is converted

to EBOPS 2010 using the concordance shown in Table 18 in order to calculate the export share relative to output. Eurostat also publishes trade in services in NACE Rev 2, which would avoid the use of the NACE Rev 2- EBOPS 2010 concordance. However, the public information is not disaggregated by destination country, which is required to calculate the export share to UK. Note that the correspondence table does not include "Travel" EBOPS code, consequently, that category is excluded from the estimation.

Unfortunately, services exports for the wholesale and retail (WR) sector are not included in the EBOPS statistics. Hence, we need to approximate their value. Doing so is based on the idea that the WR sector exports goods but embedded in those goods are services exports which are represented by the traders' margins. Hence, we approximate the value of services exports as the product of the German goods exports for the WR sector multiplied with its industry margin rate (gross margin/turnover):²⁶

$$Exp_serv_WR_{DE} = Exp_goods_WR_{DE} * \frac{Gross_margin_WR_{DE}}{Turnover_WR_{DE}} \quad (4)$$

In the same way, the services exports for WR destined to the UK is approximated as the product of equation 4 (German services exports for WR sector) with the German manufacturing export share to UK:

$$Exp_serv_WR_{DE_to_UK} = Exp_serv_WR_{DE} * Sh_exp_goods_to_UK \quad (5)$$

²⁶As $Exp_Goods_WR_{DE}$ data is available from 2014 to 2020, the value for the previous years is calculated as $Exp_{t-1} = Exp_t - \hat{\beta}_1$, in which $\hat{\beta}_1$ is obtained from a simple regression: $Exp = \beta_0 + \beta_1 Year$. Also $Gross_margin_WR$ and $Turnover_WR$ data is available from 2008 to 2020, therefore the value for the previous years (2006 and 2007) is calculated as: $X_{t-1} = X_t - \hat{\beta}_1$, in which $\hat{\beta}_1$ is obtained from a simple regression: $X = \beta_0 + \beta_1 Year$

Table 17: Correspondence EBOP 2010 -EBOP 2002

EBOP 2010 Description	EBOP 2010 code	EBOP 2002 code
Maintenance and repair services not included	SB	160
Transport	SC	205
Transport	SC	246
Travel	SD	236
Construction	SE	249
Insurance and pension services	SF	253
Financial services	SG	260
Telecommunications, computer, and information services	SI	247
Telecommunications, computer, and information services	SI	262
Research and development services	SJ1	279
Professional and management consulting services	SJ2	274
Professional and management consulting services	SJ2	278
Technical, Trade-related and other business services	SJ3	280
Technical, Trade-related and other business services	SJ3	281
Technical, Trade-related and other business services	SJ3	284
Technical, Trade-related and other business services	SJ3	272
Technical, Trade-related and other business services	SJ3	271
Technical, Trade-related and other business services	SJ3	285
Personal, cultural, and recreational services	SK	287
Government goods and services n.i.e.	SL	291
Services not allocated	SN	982

Based on: https://unstats.un.org/unsd/tradeserv/TFSITS/newsletter/Conversion_Matrix_EBOPS_2010%20rf.htm

Table 18: Correspondance EBOP 2010 - NACE Rev 2

EBOP 2010 Description	EBOP 2010 code	NACE Rev 2	NACE Rev 2 Des	Share
Transport	SC	D	Electricity, gas, steam	0.5
Transport	SC	H	Transportation and storage	1
Construction	SE	F	Construction	1
Insurance and pension	SF	K65	Insurance, reinsurance and pension funding	1
Activities auxiliary to financial services and insurance	SF	K66	Activities auxiliary to financial services and insurance	0.5
Financial	SG	K64	Financial services activities, except insurance	1
Financial	SG	K66	Activities auxiliary to financial services and insurance	0.5
Intellectual property	SH	N77	Rental and leasing activities	0.25
Telecommunication, computer and information	SI	J61	Telecommunications	1
Telecommunication, computer and information	SI	J62-J63	Computer programming, consultancy; information service activities	1
Telecommunication, computer and information	SI	N77	Rental and leasing activities	0.25
Telecommunication, computer and information	SI	S95	Repair of computers, personal, household goods	0.5
Telecommunication, computer and information	SI	S96	Other personal service activities	0.5

Telecommunication, computer and information	SI	J58	Publishing activities	1
Research and development services	SJ1	M72	Scientific research and development	1
Professional and management consulting services	SJ2	M69_M70	Legal and accounting activities; activities of head offices; management consultancy activities	1
Professional and management consulting services	SJ2	M73	Advertising and market research	1
Technical, Trade-related and other business services	SJ3	D	Electricity, gas, steam	0.5
Technical, Trade-related and other business services	SJ3	L	Real estate activities	1
Technical, Trade-related and other business services	SJ3	M71	Architecture and engineering activities; technical testing and analysis	1
Technical, Trade-related and other business services	SJ3	E	Water collection, treatment	1
Technical, Trade-related and other business services	SJ3	N77	Rental and leasing activities	0.25
Technical, Trade-related and other business services	SJ3	N78	Employment activities	1
Technical, Trade-related and other business services	SJ3	N79	Travel agency, tour operator reservation service and related activities	1

Technical, Trade-related and other business services	SJ3	N80-N82	Security and investigation activities; services to buildings and landscape activities; office administrative, office support and other business support	1
Technical, Trade-related and other business services	SJ3	M74-M75	Other professional, scientific and technical activities; veterinary activities	1
Personal, cultural and recreational services	SK	I	Accommodation and food service	1
Personal, cultural and recreational services	SK	J59-J60	Motion picture, video and television and programming	1
Personal, cultural and recreational services	SK	N77	Rental and leasing activities	0.25
Personal, cultural and recreational services	SK	P	Education	1
Personal, cultural and recreational services	SK	Q	Human health and social work activities	1
Personal, cultural and recreational services	SK	R	Creative, arts and entertainment activities	1
Personal, cultural and recreational services	SK	S94	Activities of membership organisations	1

Based on: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Table_4_EBOPS_2010-NACE_Rev2_correspondence.PNG