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## Article

# What drives Germany's exports?

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## Empirical Paper

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# What Drives Germany's Exports?

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**Abstract:** This article reviews several hypotheses that aim at explaining the development of German merchandise exports. Based on cointegration estimation techniques, we examine different determinants for their ability to explain German exports during the period 1992–2016. The estimation results indicate that, in addition to the traditional determinants (world demand and price competitiveness), other determinants, such as energy prices and the increasing fragmentation of production processes, are also crucial in explaining German exports.

**Keywords:** international trade, export demand, cointegration

**JEL Classification:** C22, F4, J3

## 1 Introduction

The question of what drives exports at the country level is one of the longest-standing discussions in international macroeconomics. Especially in Germany, which has traditionally been one of the countries with the highest exports in the world, fluctuations in merchandise exports indeed represent a substantial component of domestic economic growth volatility. Therefore, policy makers closely monitor these fluctuations.

Given Germany's export dependence and recent changes in the world economy, it seems highly relevant to analyze which factors other than the traditional export determinants (price competitiveness and foreign demand) are crucial in explaining Germany's export performance. To find out more about the driving forces of Germany's exports, our study goes beyond the standard export demand function and tests a wider range of factors and a longer time period than is typically analyzed. To assess the relative importance of the determinants, we employ the multivariate estimation technique of Johansen [1988, 1992a,b]. This approach allows for simultaneous estimation of the long-run relationship and the short-run adjustment process of the variables under consideration. Our study also examines the contribution of different determinants to the development of German exports over the more recent past.

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The remainder of the article is structured as follows. Section 2 provides a literature overview. Section 3 explains the econometric methodology and the dataset. Section 4 presents the empirical results. Section 5 summarizes the main findings of the study and concludes.

## 2 Literature overview

Research papers based on firm-level data show that exporting firms are more productive than non-exporting firms and that they boost economic growth in the respective economy [De Loecker, 2007, 2011; Hansen, 2010]. Traditionally, the demand for exports is specified as a function of a country's price competitiveness and a foreign economic activity variable [Goldstein and Khan, 1985]. Both an improvement in price competitiveness and a rise in foreign demand are expected to lead to a rise in exports. Several studies estimate export demand elasticities for Germany and find the absolute values of the long-run price elasticity to range between 0.2 and 1.0 and the long-run income elasticity to range between 0.8 and 1.6 [Senhadji and Montenegro, 1999; Hooper et al., 2000; Strauß, 2000]. Although the results of these studies suggest that traditional determinants are essential in explaining German exports, substantial unexplained residuals remain. This outcome points towards the existence of crucial unobserved or omitted variables in the traditional export demand function. Therefore, this article aims at identifying some of these additional factors.

So far, there are only very few studies that go beyond the traditional export demand function and test the relevance of variables other than price competitiveness and foreign economic activity. Based on the arguments of the new trade theory [Krugman, 1983, 1985] and the endogenous growth theory [Grossman and Helpman, 1991], such studies mainly concentrate on factors such as globalization and quality differentials of traded goods. To capture the effects of globalization, introducing linear trends and dummy variables into the regression models has become predominant in the literature [Stephan, 2005; Barrell and Pomerantz, 2007]. Although there seems to be a consensus about the overall positive effect of globalization on German exports, the interpretation of the estimated coefficients is largely intuitive and indirect. For instance, a statistically significant trend in the export demand function can be attributed to different causes and, therefore, leaves significant room for interpretation. Hence, it is inevitably important to concentrate on isolated aspects of globalization to provide specific economic reasoning for the estimation results. In this study, we focus on the ongoing fragmentation of production processes as one potential determinant.

Concerning quality differentials of traded goods, Grossman and Helpman [1991] highlighted the importance of technological competitiveness in explaining trade flows. They argued that spending more on research and development enables firms to improve their product quality leading to an increased market share relative to competitors. To control the quality differentials, some empirical studies introduced specific R&D measures or patenting activities to the traditional export demand function [Madsen, 2004]. The findings of the existing studies, however, did not yield conclusive results for the case of Germany. Therefore, it seems useful to further investigate the importance of quality aspects for German export performance.

So far, empirical studies have generated little consensus about which factors are most important in explaining German exports. Most of them have examined either the effects of globalization or the effects of quality differentials as potential determinants. The objective of this article is to combine the two strands in the literature in one empirical analysis to derive the results that are more conclusive and contribute to explaining part of the large residuals of the traditional German export demand function. Besides, our analysis goes beyond the already existing explanations and includes the aspects of energy efficiency which is a characteristic often ascribed to German products.

## 3 Empirical methodology and dataset

As we are interested in the key drivers of German exports, we first discuss potential determinants before turning to the empirical analysis of factors that affect export performance in Germany. In the following, we list the factors that our analysis takes into account.

- i. *Price competitiveness*: As pointed out earlier, the traditional determinants of export performance include the domestic price level, and the development of exports is determined by changes in relative prices and foreign demand. Since the mid-1990s, German firms put a lot of effort into restoring price competitiveness in international markets. Especially, the wage moderation policy before the outbreak of the worldwide financial crisis in 2008 helped the economy to strengthen its international competitive position vis-à-vis the rest of the world [Blanchard and Philippon, 2004]. The real effective exchange rate provides one possibility to measure international price competitiveness. It is a weighted average of a country's currency relative to an index or basket of other major currencies adjusted for the effects of inflation. A rise in the real effective exchange rate implies a worsening in international price competitiveness for a country vis-à-vis its main trading partners. In line with previous studies, we use the real effective exchange rate based on unit labor costs in the manufacturing sector (*REER*) to control for price competitiveness in our empirical analysis [Stahn, 2006]. In the case of Germany, this measure seems to be most appropriate, as German export goods mainly represent manufactured products.<sup>1</sup> Although the real effective exchange rate entails crucial information concerning price competitiveness, it does not capture the effects of quality enhancements on prices. Therefore, we take into account an explanatory variable controlling for quality aspects as well.
- ii. *Foreign demand*: The fact that German exporters have well-established links not only to highly industrialized countries but also to fast-growing emerging markets might have significantly contributed to the upsurge in exports. Although the biggest share of Germany's exports still goes to industrial countries and especially to the old members of the European Union (EU), the share of exports to the new member countries of the EU almost doubled over the period 1992–2016. German exports to emerging markets outside the EU experienced a similar pace of expansion. Well-established trade links with the BRIC countries probably allowed Germany to benefit more than its competitors from rising demand in these economies. A reason for this development often pointed out was possibly linked to the fact that the catching-up process of these countries was accompanied by rising demand for capital goods, which have traditionally constituted German export goods. Usually, empirical studies use the volume of world trade, foreign real GDP, or, in some rare cases, the demand for investment goods to model foreign demand [Sawyer and Sprinkle, 1999; Strauß, 2004; Stephan, 2005]. Other studies, however, discuss the advantages of using export market trends calculated based on import activities of the trading partner countries to measure the economic activity [Stahn, 2006; Danninger and Joutz, 2007]. This approach allows eliminating the endogeneity problem significantly. Based on their arguments, we also use real imports of Germany's main trading partners weighted by the average export share to measure foreign demand (*Demand*).<sup>2</sup>
- iii. *Fragmentation of production processes*: One additional explanation that seems worthwhile to examine is based on the progressive openness of capital markets and the ongoing integration of emerging markets into the world economy. These developments allow firms to geographically segment different production stages across the world to optimally exploit the comparative advantages of different locations. In contrast to Sinn [2006a,b, 2014], we interpret the fragmentation of production processes globally as positive economic developments. To conclude the fragmentation effect, we include the amount of domestic value added as a percentage of total production output (*Domestic VA*) into our model. A decline in domestic value added is a reflection of an increase in the share of intermediate goods. Therefore, a negative relationship between this variable and exports can be interpreted as evidence for the increased fragmentation of production processes.
- iv. *Quality differentials*: The real effective exchange rate entails important information concerning the international competitiveness of a country. However, it does not capture all aspects of competitiveness.

<sup>1</sup> For robustness purposes, we also use the real effective exchange rate based on unit labor cost as an alternative.

<sup>2</sup> Based on the assumption that Germany is a small country, the advantage of this variable is that the estimated elasticity indicates whether German exports have grown to the same extent as export markets. A value of one indicates a constant market share. A value that is smaller than one reflects a loss in global export market share. For the construction of the variable, we use constant weights that are calculated as German export share averages over the period 2000–2003.

While improvements in productivity are directly reflected in the real effective exchange rate, it neglects important factors, which cannot be attributed to changes in productivity. For example, higher prices could reflect superior design or reliability of goods. When the value of output is deflated by these higher prices, Germany appears to be less productive than its competitors, while in reality, consumers' willingness to pay is increased by higher product quality. In this context, Grossman and Helpman [1991] stress the importance of innovation in developing new products that are of higher quality than similar goods available on the market. Based on their arguments, we use R&D expenditure as a proxy variable to control for quality differentials. More specifically, we employ the gross R&D expenditure share in GDP relative to this share of OECD countries (*R&D*) in our empirical estimations.

- v. *Foreign direct investment activities*: Traditionally, two general motives of FDI strategies can be distinguished. The market seekers are companies that invest in a particular region to increase their market share in that region. The resource and efficiency-seeking companies invest abroad to lower production costs, for example, access to labor at lower costs. While market-seeking FDI activities can be regarded as substitutes for exports, resource-seeking FDI activities might be complements of exports. A study by the Bundesbank [2006] establishes an empirical link between Germany's FDI and trade flows with respect to a very specific region, namely the new member countries of the EU.<sup>3</sup> The results indicate that increased outward FDI from Germany to new EU member countries appears complementary to an increase in both imports and exports to these countries. However, in addition to Eastern Europe, which has become one of the most important destinations for Germany's foreign direct investment, German investment activities in other countries and especially in the BRIC countries also increased significantly since the mid-1990s. Therefore, it is interesting to analyze the effects of Germany's overall outward FDI activities on its overall export performance. To capture the effects of the internalization of production processes, we include Germany's outward FDI stock deflated by the GDP deflator of the euro area countries (*FDI*) to our baseline model.<sup>4</sup>
- vi. *Efficient technologies and alternative energy sources*: Albeit the label "Made in Germany" is regularly seen as synonymous to high-quality goods, German products are increasingly said to be also exceptionally energy-efficient. With increased energy conscientious attitudes around the world, the world demand for energy-efficient products and alternative energies has significantly increased. Concerning energy-efficient technology and new energy solutions, Germany is one of the global market leaders. In particular, Germany's Renewable Energy Sources Act has helped the economy to become the world leader in using solar photovoltaic and solar thermal systems and to develop a thriving manufacturing and R&D industry in this field.<sup>5</sup> According to the German Renewable Energy Federation [2008], the world market volume for renewable energy sources has doubled from €30 to €60 billion, since the turn of the century and is estimated to increase further to €400 billion by 2020. To our knowledge, no studies have yet examined the effects of energy prices on German exports. Using the petroleum crude price index as an indicator of energy prices in general (*Energy*), we investigate the relationship between the oil price and German exports.

Having outlined the potential factors affecting Germany's exports, we now turn to the estimation technique. We employ the multivariate cointegration estimation approach to assess the relative importance of the factors discussed earlier. Theoretically, the export demand function reflects a long-run steady-state relationship. From an econometric point of view, this would imply a cointegration relationship between the variables under consideration. We apply the Johansen's [1992a,b] cointegration technique to determine

<sup>3</sup> The relationship between trade, foreign direct investment, and the activities of multinational corporations is studied in detail by Kleinert [2001].

<sup>4</sup> We use the FDI stock variable rather than the flow variable, since stocks allow us to treat the FDI strategy as a long-run phenomenon, while looking at year-on-year evolution of FDI might blur the proper FDI strategy.

<sup>5</sup> The Renewable Energy Sources Act (EEG) draws on more than 15 years of experience. It has its origin in The Electricity Feed Act (StrEG) which became effective in 1991. In 2004, this act was replaced by The Renewable Energy Sources Act (EEG). According to the International Energy Agency [International Energy Agency (IEA), 2008], it is the most important and successful instrument to promote the expansion of renewable energies in the electricity sector.

the number of cointegration vectors in each model.<sup>6</sup> The Johansen's procedure is based on a multivariate vector autoregression (VAR) model which can be transformed into a vector error correction model (VECM) to test for the number of cointegration relationships. Therefore, we conduct different specifications of an unrestricted VECM of the following general form:

$$\Delta z_t = \alpha \beta' (z_{t-1}) + \sum_{i=1}^{p-1} \Gamma_i \Delta z_{t-1} + \psi D_t + \varepsilon_t, \quad (1)$$

where  $z_t$  is a vector of endogenous I(1) variables identified through the Augmented Dickey-Fuller test,  $D_t$  represents the set of stationary exogenous variables including seasonal dummies and a constant,  $p$  indicates the lag length of the model, which was identified in the VAR set up employing the Hannan–Quinn information criterion. The  $\alpha$  vector measures the speed of adjustment to restore a long-run equilibrium and the  $\beta$  vector includes estimates of the long-run cointegration relationships between the variables.  $\varepsilon_t$  represents the remaining error term.

The list in the Appendix details the variables used in our study. All estimations use quarterly observations between 1992Q1 and 2016Q4. Data before 1992 are either missing or are dropped due to unification-related fluctuations. We use all variables in logs. This procedure allows us to interpret the result as export elasticities.<sup>7</sup> Since seasonally unadjusted data are used, constant and centered seasonal dummies are included in the estimations. The results of the long-run relationship can be interpreted as a structural export demand function.

## 4 Estimation results

We consider five alternative model specifications of our export demand function to derive the final cointegration relationship. This final specification (Model 6) comprises all significant variables, which were identified in the previous estimations. Table 1 shows the different specifications considered in our analysis.

Model 1 includes of two explanatory variables, *Demand* and *REER*. The traditional model is extended by additional variables to analyze the relevance of this potential determinant (Models 2–5). The final cointegration relationship (Model 6) includes all statistically significant variables identified in the previous estimations. We will elaborate on the variables entering Model 6 below. To test for the number of cointegration relations in the considered models, we apply the maximum eigenvalue. Table 2 shows the results. They suggest a single cointegration relation for each model specification. Unlike a correlation that measures how well two or more variables move together, cointegration rather measures whether the difference between their means remains constant.

Together with the weak exogeneity of the explanatory variables leads us to continue with the analysis of a single equation error correction model. This allows us to interpret the long-run relationship as a structural export function. As in standard I(1) cointegration, the timing of variables in the cointegrating relation does

**Table 1.** Variables included in the different models

| Model | Exports | Demand | REER | R&D | Energy prices | FDI | Domestic VA |
|-------|---------|--------|------|-----|---------------|-----|-------------|
| 1     | x       | x      | x    |     |               |     |             |
| 2     | x       | x      | x    | x   |               |     |             |
| 3     | x       | x      | x    |     | x             |     |             |
| 4     | x       | x      | x    |     |               | x   |             |
| 5     | x       | x      | x    |     |               |     | x           |
| 6     | x       | x      | x    |     | x             |     | x           |

<sup>6</sup> The models under consideration entail more than two variables. Therefore, more than just one linear independent cointegration vector could exist. The Johansen's [1992a,b] procedure allows to test for more than just one cointegration vector, whereas the Engle and Granger's [1987] methodology only allows to test for one cointegration relationship and would, therefore, yield inconclusive results.

<sup>7</sup> Since our data do not include zero values, we do not need to adjust the data before converting them into logs.



**Table 2.** Johansen's cointegration test

| Model 1  |                      |                      | Model 2  |                       |                      |
|----------|----------------------|----------------------|----------|-----------------------|----------------------|
| H0: rank | Trace test<br>[Prob] | Max test<br>[Prob]   | H0: rank | Trace test<br>[Prob]  | Max test<br>[Prob]   |
| 0        | 44.653***<br>[0.003] | 25.327**<br>[0.018]  | 0        | 72.332***<br>[0.000]  | 37.686***<br>[0.003] |
| 1        | 19.326*<br>[0.067]   | 12.013<br>[0.185]    | 1        | 34.646*<br>[0.057]    | 18.102<br>[0.174]    |
| 2        | 7.313<br>[0.110]     | 7.313<br>[0.111]     | 2        | 16.545<br>[0.150]     | 12.020<br>[0.185]    |
| Model 3  |                      |                      | Model 4  |                       |                      |
| H0: rank | Trace test<br>[Prob] | Max test<br>[Prob]   | H0: rank | Trace test<br>[Prob]  | Max test<br>[Prob]   |
| 0        | 64.402***<br>[0.005] | 37.484***<br>[0.003] | 0        | 058.588***<br>[0.004] | 33.641***<br>[0.007] |
| 1        | 26.918<br>[0.293]    | 12.644<br>[0.592]    | 1        | 24.947<br>[0.163]     | 19.285*<br>[0.089]   |
| 2        | 14.274<br>[0.271]    | 8.305<br>[0.512]     | 2        | 5.661<br>[0.735]      | 3.801<br>[0.880]     |
| Model 5  |                      |                      | Model 6  |                       |                      |
| H0: rank | Trace test<br>[Prob] | Max test<br>[Prob]   | H0: rank | Trace test<br>[Prob]  | Max test<br>[Prob]   |
| 0        | 64.249***<br>[0.000] | 35.174***<br>[0.004] | 0        | 111.458***<br>[0.000] | 51.920***<br>[0.000] |
| 1        | 29.076*<br>[0.060]   | 18.923*<br>[0.099]   | 1        | 59.539<br>[0.110]     | 27.113<br>[0.181]    |
| 2        | 10.153<br>[0.269]    | 8.465<br>[0.333]     | 2        | 32.425<br>[0.366]     | 19.588<br>[0.268]    |

The table shows the estimates of the Johansen's cointegration test for Models 1–6 as specified in Table 1. \*\*\*, (\*\*), [\*] denote significance at 1, (5), [10%] level, respectively.

not interfere with the cointegration property (Nielson, 2005). Therefore, we continue with the estimation of the conditional single equation error correction model of the following general form:

$$\Delta z_t = \alpha(z_{t-1} - \beta x_{t-1}) + \sum_{j=1}^{p-1} \gamma_j \Delta z_{t-j} + \sum_{j=0}^{p-1} b_j \Delta x_{t-j} + \Psi D_t + \varepsilon_t \quad (2)$$

where  $z_t$  now represents German exports only.  $x_t$  is a vector of the determinants, which are found to be weakly exogenous. Vector  $\alpha$  measures again the speed of adjustment to restore a long-run equilibrium and the  $b$  vector includes estimates of the long-run cointegration relationship between the variables. The short-run dynamics are now determined not only by the lagged first differences of the endogenous variables  $g_j$  but also by the lagged first differences of the exogenous variables  $b_j$ .

Table 3 contains the reduced rank cointegration relations with the numbers in parentheses and brackets representing the standard errors (SE) and the statistical significance levels, respectively. Table 2 also shows the adjusted  $R^2$ , the results of the Breusch–Godfrey LM test for autocorrelation (LM(4)), and the normality test using the Jarque-Bera criterion. The results suggest that in all models, the residuals are normally distributed at 1% significance level and are not autocorrelated up to the fourth order. For the final cointegration relationship (Model 6), a Wald test is run to examine whether the long-run impact of foreign demand is significantly different from unity.

The traditional determinants are highly significant and have the expected signs in all models. The estimation results are also robust to changes in model specifications. Furthermore, the estimation results indicate that two out of four additional determinants are crucial in explaining German exports.

**Table 3.** Reduced rank cointegration relations

| Model                 | 1                    | 2                    | 3                    | 4                    | 5                    | 6                          |
|-----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------------|
| $\beta$ Exports       | 1                    | 1                    | 1                    | 1                    | 1                    | 1                          |
| $\beta$ Demand        | -0.973***<br>(0.067) | -0.976***<br>(0.057) | -0.815***<br>(0.041) | -0.943***<br>(0.122) | -0.910***<br>(0.056) | -1<br>[0.113] <sup>a</sup> |
| $\beta$ REER          | 0.630***<br>(0.237)  | 0.746***<br>(0.217)  | 0.682***<br>(0.131)  | 0.687***<br>(0.229)  | 0.605***<br>(0.210)  | 0.426***<br>(0.142)        |
| $\beta$ R&D           |                      | 0.030<br>(0.835)     |                      |                      |                      |                            |
| $\beta$ Energy prices |                      |                      | -0.081***<br>(0.022) |                      |                      | -0.071***<br>(0.021)       |
| $\beta$ FDI           |                      |                      |                      | -0.013<br>(0.079)    |                      |                            |
| $\beta$ Domestic VA   |                      |                      |                      |                      | 1.304*<br>(0.796)    | 1.837***<br>(0.643)        |
| $\alpha$ Exports      | -0.256***<br>(0.071) | -0.294***<br>(0.048) | -0.377***<br>(0.063) | -0.257***<br>(0.049) | -0.213***<br>(0.065) | -0.424***<br>(0.069)       |
| Adj. R <sup>2</sup>   | 0.638                | 0.600                | 0.645                | 0.581                | 0.614                | 0.651                      |
| S.E.                  | (0.027)              | (0.028)              | (0.027)              | (0.029)              | (0.028)              | (0.027)                    |
| LM(4)                 | [0.658]              | [0.359]              | [0.701]              | [0.341]              | [0.058]              | [0.169]                    |
| JB                    | [0.739]              | [0.349]              | [0.949]              | [0.603]              | [0.139]              | [0.942]                    |

The table shows the estimates of the long-run coefficients for Models 1–6 as specified in Table 1.

\*\*\*, (\*\*), [\*] denotes significance at 1, (5), [10%] level, respectively; standard errors are given in parentheses.

<sup>a</sup>Results of the Wald test:  $H_0: \beta_{\text{demand}} = -1$ :  $p$ -values from the LR-statistics are given in brackets.

The energy variable turns out to be highly significant. A rise in the oil price leads to an increase in German exports in the long run. This positive long-run relationship between the oil price and German exports can be interpreted as evidence of increased global demand for energy-efficient products and alternative energy technologies.

The estimation results further suggest that increased specialization by the ongoing fragmentation of production processes benefits the German export sector. In our analysis, we use the share of domestic value added in total output as a proxy of specialization. The sign of the coefficient indicates that a decline in the share of domestic value added in total output improves Germany's export performance. This indicates that increased regionalization of production processes contributes to the export performance in the long run.

While the energy variable and the domestic value-added variable turn out to be statistically significant determinants, the quality variable and the FDI variable seem to be statistically insignificant in explaining German exports. Hence, we do not find support for the hypothesis according to which Germany-specific quality aspects are crucial in explaining German export performance. Even in the case when the R&D variable enters the export demand equation in its lagged representation because of the argument that the contemporaneous effects of quality variables are unlikely, the results do not change. One reason for this outcome might be linked to the fact that R&D expenditure only entails information about the input to innovation but not information about successful research and therefore does not appropriately capture all quality aspects. In this respect, a more disaggregated approach might shed more light on the relationship between innovation and export performance [Cassiman et al., 2010].

The FDI variable also turns out to be statistically insignificant in explaining German exports. This outcome might be linked to the fact that the results of the Wald test for weak exogeneity suggest that the  $\alpha$ -coefficient of the FDI variable is significantly different from zero indicating that FDI cannot be treated as weakly exogenous. However, if we treat the FDI variable as endogenous as well, we end up with a multivariate system which cannot be interpreted as a structural export demand function.

Based on the before-mentioned conditions, our final export demand model is given by the following explanatory variables: *Demand*, *REER*, *Energy prices*, and *Domestic VA*. The adjustment coefficient of the



model suggests that over 90% of the disequilibrium is corrected in four quarters, which is a common outcome when analyzing export demand models [Danninger and Joutz, 2007]. The adjusted  $R^2$  of Model 6 is higher in comparison with Models 1–5. This indicates that our final demand model succeeds in explaining some of the unexplained residuals of the other models. Since the demand elasticity is close to one in Models 1–5, we perform a Wald test to examine whether the long-run impact of foreign demand is significantly different from the one in Model 6. The test result suggests that we can treat demand as unit elastic. Hence, given that everything else remains unchanged, a 1% increase in global demand leads to an increase in German exports of the same size. The price elasticity is around 0.4%, indicating that a 2.5% real depreciation of the Euro will lead to a 1% increase in exports. The empirical results concerning the relationship between the oil price and German exports appear particularly interesting. An increase in oil prices by 1% leads to an increase in exports by 0.07%. This outcome can be interpreted as some evidence for the increasing demand for alternative energy solutions and energy-efficient products. Since Germany is striking in these industries, the scarcity in natural energy resources and the high oil prices benefit the German export sector. Another interesting outcome is that a decline of the share of domestic value added in total output increases German exports by almost 2%. This result has interesting management implications: Obviously, the exports of German manufactures increase with a stronger use of international fragmentation of production processes.

## 5 Summary and conclusions

In this study, we examine different hypotheses for their ability to explain German export performance during the period 1992–2016. The estimation results of the single-equation error correction model indicate that world demand, price competitiveness, energy prices, and the fragmentation of the production process are the main factors explaining Germany's exports. By contrast, we do not find conclusive evidence of Germany's exports being determined by R&D expenditure or FDI activities. The econometric results suggest that world demand is one of the key drivers of German exports. According to the estimation output, it is possible to treat demand as unit elastic. Hence, given that everything else remains unchanged, a 1% increase in global demand leads to an increase in German exports of the same size.

Further, the results indicate that German exporters have benefited from the ongoing specialization. Because German companies have optimized their value chain of production in such a way as to make use of the comparative advantages of individual firms and locations, they were able to increase their exports.

Price competitiveness plays a comparatively smaller role in explaining export growth. Even though prolonged effort in containing costs through wage moderation was significant, the effect is, in particular, diluted by the nominal appreciation of the euro before the outbreak of the worldwide financial crisis.

Further, the results of the study indicate that Germany particularly benefited from the ongoing globalization and the possibility of optimizing the value chain of production globally. Hence, the EU enlargement and the worldwide liberalization of capital and goods markets enable German manufactures to make use of the comparative advantages of different locations. Therefore, Germany's policy makers should continue to safeguard open borders as well as strong trade and investment links between economies worldwide.

The results on the relationship between the oil price and exports are of particular interest. The positive long-run relationship supports the argument that with rising energy prices and natural resources becoming scarce, the demand for energy-efficient products and alternative energy technologies increases. Since Germany is leading in these industries, the result might support the view that German manufacturers and the export sector strongly benefit from this development. However, further research is required to address this link more specifically. An alternative interpretation of the result might be that German exporters benefit from the petrol dollar effect. For instance, an analysis of a disaggregated product level might lead to more insights on that topic.

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## Appendix

*Description of the variables used in the analysis: (Sample period: 1992Q1-2016Q4).*

### Exports

Germany's total goods export volumes  
Index 2000 = 100  
*Source:* German Federal Statistical Office

### Demand

Real imports of Germany's main trading partners (the first 15 destinations for Germany's exports for the considered period on average) weighted by the average export share of the considered country.

$$\text{Demand}_t = \sum_i (x_i M_{it})$$

With  $x_i = X_i/X_G$  where  $x_i$  is Germany's exports to country  $i$  and  $X_G$  is Germany's total exports. The ratio is averaged over the period 2000–2003.  $M_i$  is real imports of country  $i$  in period  $t$ .

Index 2000 = 100  
*Source:* IFS

### REER

The real effective exchange rate is based on relative unit labor costs in the manufacturing sector.

Index 2000 = 100  
*Source:* IFS

### R&D

Germany's gross expenditure on R&D as a percentage of GDP relative to gross expenditure on R&D as a percentage of GDP of OECD total.

Index 2000 = 100  
*Source:* OECD

### Energy prices

Crude oil price index  
Index 2000 = 100  
*Source:* IFS

### FDI

Germany's outward FDI stock is deflated by the GDP deflator of euro area  
Index 2000 = 100  
*Source:* OECD

### Domestic VA

Domestic value added as a percentage of total production output  
Index 2000 = 100  
*Source:* German Federal Statistical Office