WHAT DETERMINES THE MEDIUM AND HIGH TECHNOLOGY PRODUCTS EXPORTS: THE CASE OF GERMANY

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ABSTRACT

High-tech products are a key element of today's international trade. Ever-increasing technological development and constant globalization have made high-tech products indispensable. Innovation is the cornerstone of the production of medium and high-tech products. A key element to mention is that high-tech products are part of many intermediate goods. Germany is an example of a country specializing in the production of such products. The question that arises is what factors are the factors that drive the exports of high-tech products. One answer could be spent on research. Of course, in order for expenditure on R&D to be fully considered a key factor, it must be implemented through entrepreneurship in the real economy. It could also be foreign direct investment. However, there may be cases where foreign investments are a factor in the diffusion of know-how. Because of these ambiguities, a more complete framework for analysis should be created. This study will attempt to create a framework of analysis for exports of high-tech products using Germany as a case study. The methodology applied is the multiple linear regression - ordinary least squares (OLS).

Keywords: Medium High-Tech Products, Exports, OLS.
INTRODUCTION

Germany is one of the strongest economies in the global economic system. Especially, Gross national revenue in Germany was 3,458.5 billion Euro in 2018, per capita was 41,717 Euro and, gross domestic product was 3,386.0 billion Euro (Eurydice, 2021). Germany is among the countries specializing in the development of new technologies according to Braja and Gemzik-Salwach (2020). Specifically, they state that from the 47,682 companies in the EU were manufacturing high-tech goods, 7,716 were in Germany, with a noteworthy contribution of corporations located in Germany (156,940 million EUR). Germany has relied on technological development for its economic growth (Siebert and Stolpe, 2001). According to Naudé and Nagler (2017) Germany should enhance innovation to be able to become more competitive in high technologies. Considering Kaldor’s law (the growth rate is positively associated to the growth rate of its manufacturing or industrial sector) then the importance of Germany's high and medium tech products play a vital role. The question that needs to be answered is this: what are the factors that determine the exports of Germany's medium- and high-tech products? The answer to this question will be attempted by this research.

It is interesting to present some economic data regarding the economy of Germany. Figure 1. shows the Real Effective Exchange Rate (REER) and the percentage annual growth of Exports of Goods and Services for Germany for 1993-2018 and Figure 2. shows the Intermediate goods Country Growth to World in %, Consumer goods Country Growth to World in percent and the Capital goods Country Growth to World in percent of Germany for the period 1993-2018.

Figure 1: The Real Effective Exchange Rate (REER) and the percentage annual growth of Exports of Goods and Services for Germany for 1993-2018. (Author’s elaboration based on World Bank, 2021a,b)

1 See: Keho (2018).
As far as the REER of Germany is concerned, there is no large variation and the average is 104.09, while the percentage annual growth of Exports of Goods and Services for Germany shows a high variation of 34.8. Germany has a partial equal distribution in terms of the share of exports between intermediate, capital and consumer goods. Essentially, the average price for the period under consideration is for intermediate goods the price 4.08 for capital goods the price 4.21 and for consumer goods it is the price 4.33.

The current study clarifies the determinants of the medium and high-tech product exports of Germany. The rest of this research effort is formed as follows: in the second part, the review of the literature is mentioned. In the third part of this research the methodology is cited. In the fourth part the outcomes of the regression are cited. The last part concludes. This research was based on the Linear Regression Analysis - Ordinary Least Squares (OLS). The next section presents a concise reference to the literature.

**A BRIEF REVIEW OF THE LITERATURE**

Exports with a high technological content are a key objective of the economic policies of many countries. The literature on the subject of high-tech products is rich. There is a plethora of research texts dealing with this subject. Surveys such as Posner, (1961); Vernon, (1966); Keesing, (1965); Kenen, (1965); Krugman, (1980); Krugman (1979); Grossman and Helpman, (1991); Greenhalgh, (1990); Amendola et al., (1993); Archibugi and Michie, (1998); Helpman, (1999); Krugman, (1992); Bernard et al., (2007); Soete, (1981); Fagerberg, (1988); Amable and Verspagen, (1995); Montobbio and Rampa, (2005); Eaton and Kortum, (2001); Spulber, (2008); Falk, (2009) have shown the importance and weight of high-tech products. Surveys such as Mani, (2000); Lall, (2000); Fagerberg, (1997); Guerrieri and Milana, (1995); Kadeřábková and Srholec (2001); Hatzichronoglou (1997); Lee and Hong (2010); and, Srholec (2006) have shown the potential of high-tech products.

A key point of analysis is the determinants of high-tech products. Surveys such as Seyoum (2005); Braunerhjelm and Thulin (2008); Alemu (2013); Tebaldi (2011); Zhang, (2007); Gokmen, and Turen (2013); Srholec, (2007) have tried defining the determinants of high-tech products. For instance, natural resources, workforce, economic and political stability, educational status, density of R&D activities, innovation may be some of the determinants high-tech products (Kabaklarlı, et al. 2017). Research and development expenditure is a key factor for high-tech products. Surveys such as Wakelin, (2001); Fraumeni & Okubo, (2002); Falk, (2007); Koellinger, (2008); Paasi, (1998); Griliches, (1980); Mansfield, (1988); Cohen...
& Levinthal, (1989); Jovanovic, & Nyarko, (1995); Adams & Griliches, (1996); Madden, Savage, & Bloxham, (2001); Maloney & Clare, (2007) have shown the importance of R&D expenditure. The following section explains the methodology to be followed.

**METHODOLOGY AND DATA**

This study investigates the factors that determine the medium and high-tech exports of Germany. This research effort examines the percentage of Medium and High-tech exports (% manufactured exports) of Germany. The trading partners selected are France, Netherlands, United Kingdom, Italy and, United States. The countries have been selected because for most of the period under review they are among the five export destinations of Germany for the period under review. The databases for this study are the OECD, World Bank and WITS. The period and the examination country have been selected principally and mostly due to the availability of data. The period is 1993-2018. Furthermore, the period has been chosen because it covers a sufficient time period analysis.

This research applies multiple-regression model as an estimator of annual time series data. The dependent variable is Medium and High-tech exports of Germany. The study model expresses the Medium and High-tech exports of Germany as a function of: firstly, the gross domestic spending on R&D of Germany, secondly, the intermediate goods - export product share of Germany, thirdly, the exchange rate (XR) of Germany, fourthly, the multifactor productivity (MFP) of Germany, moreover, the industrial production (IPI) of France, Netherlands, United Kingdom, Italy and, United States and finally the GDP growth of France, Netherlands, United Kingdom, Italy and, United States. The above are the independent variables.

It can be expressed by the following formula:

\[ \text{MHTExp} = f(\text{GrDSpRD, InterEx, ExchRat, MultProd, IndProd GDPGr}) \]  \hspace{1cm} (1)

The study used the traditional Multiple Regression technique. The linear regression model can be scripted as:

\[ Y_i = B_0 + B_1X_{i1} + B_2X_{i2} + ... + B_KX_{iK} + e_i \]  \hspace{1cm} (2)

Where: \( Y_i \) = ith observation on the dependent variable, \( X_{ij} \) = ith observations on the jth independent variable, \( e_i \) = ith observation on the error term, \( B_0, ..., B_K \) = the parameter estimates, \( K \) = the number of independent variables, \( n \) = number of observations (Anghelache et al., 2014). Especially, the traditional Ordinary Least Squared (OLS) technique is used (Hutcheson, 2011).

An Ordinary Least Square model can be described as follows:

\[ y = b_0 + b_1x_1 + ... + b_kx_k + u \]  \hspace{1cm} (3)

---

2 Multiple linear regression assumptions:
1: Model: \( Y = \beta_0 + \beta_1X_1 + ... + \beta_kX_k + U \)
2: The observed data \( \{(Y_i;X_{i1};...,X_{iK}); i = 1;...,n\} \) is a random sample from the population.
3: None of the explanatory variables has constant values and there is no perfect linear relationships among the explanatory variables.
4: Zero conditional mean: \( \text{E}(U/X_1;...;X_k) = 0 \)
5: Homoskedasticity: \( \text{Var}(U/X_1;...;X_k) = \text{Var}(U) = \sigma^2 \)
6: Normality: \( U / X_1;...;X_k \sim N(0;\sigma^2) \)

3 See: Appendix.
Where: \( y, x_1, x_2 \ldots x_k \) are the observed random scalars; \( \epsilon \) is the error or unobservable random disturbance; and \( b_0, b_1, b_2 \ldots b_k \) are the constants or parameters that will be assessed (Woolridge, 2010).

Very important in regression is that the error terms are independent of each other. The Durbin-Watson test determines whether is a (linear) correlation between the error term for one observation and the next. The Durbin-Watson test can be expressed as:

\[
d = \frac{\sum_{i=1}^{n} (e_i - e_{i-1})^2}{\sum_{i=1}^{n} e_i^2}
\]

(4)

where the \( e_i = y_i - \hat{y}_i \) are the residuals, \( n \) is the number of elements in the sample and \( k \) is the number of independent variables. A value of \( d = 2 \) means there is no autocorrelation. A value substantially below 2 means that the data is positively autocorrelated. A value of \( d \) substantially above 2 means that the data is negatively autocorrelated.

The Shapiro-Wilk's test or Shapiro test is a normality test. The null hypothesis of Shapiro’s test is that the population is distributed normally. The formula is the following:

\[
W = \frac{\left( \sum_{i=1}^{n} a_i x_i \right)^2}{\sum_{i=1}^{n} \left( x_i - x \right)^2}
\]

(5)

Where the \( x_{(i)} \) is the ith smallest number in the given sample, the mean \( (x) (x_1+x_2+\ldots+x_n)/n \) i.e the sample mean and \( a_i \) is coefficient that can be calculated as \( (a_1,a_2,\ldots,a_n) = (m^T V^{-1})/C \). Here \( V \) is the covariance matrix, \( m \) and \( C \) are the vector norms that can be calculated as \( C= ||V^{-1}m|| \) and \( m = (m_1, m_2,\ldots, m_n) \).

The Breusch-Pagan-Godfrey test is:

\[
N * R^2 \text{ (with } k \text{ degrees of freedom)}
\]

(6)

Where, \( n \) = sample size, \( R^2 = R^2 \) (Coefficient of Determination) of the squared residuals from the original regression and \( k \) = number of independent variables.

The study sets up the estimated multiple-regression model to test the above-mentioned hypotheses as follows:

\[
MHTExpGerm = \beta_0 + \beta_1 GrDSpRDGerm + \beta_2 InterExpGerm + \beta_3 ExchRatGerm + \beta_4 MultProdGerm + \beta_5 IndProdFrt + \beta_6 IndProdNeth + \beta_7 IndProdUK + \beta_8 IndProdIt + \beta_9 IndProdUS + \beta_{10} GDPGrFrt + \beta_{11} GDPGrNeth + \beta_{12} GDPGrUK + \beta_{13} GDPGrIt + \beta_{14} GDPGrUS + \epsilon
\]

(7)

Table 1. shows the dependent variable and the explanatory variables of the model.

### Table 1.

#### The Dependent Variable and the Explanatory Variables of the Model

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>68.75</td>
<td>2.21</td>
<td>23.04</td>
<td>0.845</td>
<td>85.9</td>
<td>86.8</td>
<td>78.9</td>
<td>80.2</td>
<td>105.7</td>
<td>-0.62</td>
<td>1.25</td>
<td>2.48</td>
<td>-0.85</td>
</tr>
<tr>
<td>1994</td>
<td>69.08</td>
<td>2.13</td>
<td>23.61</td>
<td>0.830</td>
<td>87.5</td>
<td>90.0</td>
<td>82.7</td>
<td>84.5</td>
<td>112.1</td>
<td>2.35</td>
<td>2.96</td>
<td>3.84</td>
<td>2.15</td>
</tr>
<tr>
<td>1995</td>
<td>69.47</td>
<td>2.14</td>
<td>23.97</td>
<td>0.713</td>
<td>88.2</td>
<td>92.7</td>
<td>85.1</td>
<td>86.0</td>
<td>118.7</td>
<td>2.1</td>
<td>3.11</td>
<td>2.53</td>
<td>2.88</td>
</tr>
<tr>
<td>1996</td>
<td>70.31</td>
<td>2.14</td>
<td>22.33</td>
<td>0.769</td>
<td>88.9</td>
<td>93.5</td>
<td>87.2</td>
<td>87.2</td>
<td>116.8</td>
<td>0.29</td>
<td>3.49</td>
<td>2.49</td>
<td>1.26</td>
</tr>
<tr>
<td>1997</td>
<td>70.87</td>
<td>2.19</td>
<td>22.53</td>
<td>0.887</td>
<td>90.4</td>
<td>97.5</td>
<td>86.7</td>
<td>89.4</td>
<td>121.3</td>
<td>0.23</td>
<td>4.32</td>
<td>4.97</td>
<td>1.83</td>
</tr>
<tr>
<td>1998</td>
<td>71.73</td>
<td>2.22</td>
<td>21.5</td>
<td>0.900</td>
<td>90.8</td>
<td>101.6</td>
<td>88.4</td>
<td>92.3</td>
<td>122.8</td>
<td>0.48</td>
<td>4.66</td>
<td>3.7</td>
<td>1.81</td>
</tr>
<tr>
<td>1999</td>
<td>72.56</td>
<td>2.35</td>
<td>20.57</td>
<td>0.938</td>
<td>91.6</td>
<td>104.3</td>
<td>91.0</td>
<td>96.5</td>
<td>122.5</td>
<td>1.14</td>
<td>5.03</td>
<td>3.29</td>
<td>1.62</td>
</tr>
<tr>
<td>2000</td>
<td>72.97</td>
<td>2.41</td>
<td>20.59</td>
<td>1.083</td>
<td>92.7</td>
<td>108.6</td>
<td>95.9</td>
<td>99.0</td>
<td>127.2</td>
<td>0.92</td>
<td>4.19</td>
<td>3.5</td>
<td>3.78</td>
</tr>
</tbody>
</table>
Table 2. shows the explanation of the variables of the model.

Table 2.

The Variables of the Model.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MHTExpGermGerm</td>
<td>stands for Medium and High-tech exports (% manufactured exports) 1993-2018 Germany</td>
</tr>
<tr>
<td>$\beta_0$</td>
<td>stands for the constant amount or the intercept</td>
</tr>
<tr>
<td>$\beta_i$</td>
<td>are coefficients of the explanatory variables</td>
</tr>
<tr>
<td>GrDSpRDGermGerm</td>
<td>stands for Gross domestic spending on R&amp;D Total, % of GDP, 1993–2018 Germany</td>
</tr>
<tr>
<td>InterExpGerm</td>
<td>stands for Intermediate goods - Export Product Share (%) 1993-2018 Germany</td>
</tr>
<tr>
<td>ExchRatGerm</td>
<td>stands for Exchange rates Total, National currency units/US dollar, 1993–2018 Germany</td>
</tr>
<tr>
<td>MulProdGerm</td>
<td>stands for Multifactor productivity Total, 2015=100, 1993–2018 Germany</td>
</tr>
<tr>
<td>IndProdFr</td>
<td>stands for Industrial production Total, 2015=100, 1993–2018 France</td>
</tr>
<tr>
<td>IndProdNeth</td>
<td>stands for Industrial production Total, 2015=100, 1993–2018 Netherlands</td>
</tr>
<tr>
<td>IndProdUK</td>
<td>stands for Industrial production Total, 2015=100, 1993–2018 United Kingdom</td>
</tr>
<tr>
<td>IndProdIt</td>
<td>stands for Industrial production Total, 2015=100, 1993–2018 Italy</td>
</tr>
<tr>
<td>IndProdUS</td>
<td>stands for Industrial production Total, 2015=100, 1993–2018 United States</td>
</tr>
<tr>
<td>GDPGrFr</td>
<td>stands for GDP growth (annual %) 1993-2018 France</td>
</tr>
<tr>
<td>GDPGrNeth</td>
<td>stands for GDP growth (annual %) 1993-2018 Netherlands</td>
</tr>
<tr>
<td>GDPGrUK</td>
<td>stands for GDP growth (annual %) 1993-2018 United Kingdom</td>
</tr>
<tr>
<td>GDPGrIt</td>
<td>stands for GDP growth (annual %) 1993-2018 Italy</td>
</tr>
<tr>
<td>GDPGrUS</td>
<td>stands for GDP growth (annual %) 1993-2018 United States</td>
</tr>
<tr>
<td>$e$</td>
<td>stands for the error term</td>
</tr>
<tr>
<td>$t$</td>
<td>stands for the year from the period 1993-2018</td>
</tr>
<tr>
<td>$i$</td>
<td>stands for the country</td>
</tr>
</tbody>
</table>

Source: (Author’s elaboration)

The next part illustrates the results of linear regression. Table 3. displays the regression results.

Table 3.

Regression Results

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MHTExpGerm</td>
<td></td>
</tr>
<tr>
<td>GrDSpRDGerm</td>
<td>-1.270 (1.724)</td>
</tr>
<tr>
<td>InterExpGerm</td>
<td>-0.815*** (0.191)</td>
</tr>
<tr>
<td>ExchRatGerm</td>
<td>3.768** (1.303)</td>
</tr>
<tr>
<td>MulProdGerm</td>
<td>0.125 (0.116)</td>
</tr>
<tr>
<td>IndProdFr</td>
<td>-0.071 (0.080)</td>
</tr>
<tr>
<td>IndProdNeth</td>
<td>-0.025 (0.042)</td>
</tr>
</tbody>
</table>

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The outcomes of linear regression confirm the functionality of the above model. The conclusions of this study are exhibited in the next section.

**CONCLUSION**

From the analysis of the data, we observed that the model constructed in this study has a high interpretative ability. The presented model displays the functionality and significance of the selected independent variables. Adjusted R² is high, with a value of 0.956. This means that the model built in this research explains the relationship between independent variables and the dependent one. The greater the Adjusted R² the better the model fits to the data. The variables `GrDSpRDGerm`, `InterExpGerm`, `IndProdFr`, `IndProdNeth`, `IndProdUK`, `GDPGrNeth`, `GDPGrUK` have a negative effect on the Medium and High-tech exports whereas the others variables have a positive effect.

Medium and high-tech products are desired goal of any state. Germany is a country in the current economic system with a significant presence in this productive sector. From what is observed by the above model, the exports of medium and high-tech products of Germany are affected mostly by the exchange rate and by the exports of the country's intermediate goods. The participation in global value chains and the role of the exchange rate may be of particular importance. Further research is needed to establish a satisfactory analytical framework for Medium and High-tech exports.

**Reference**


2018/TradeFlow/Export/Indicator/XPRT-PRDCT-SHR/Partner/WLD/Product/UNCTAD-SoP2


World Bank (2021a). Real effective exchange rate index (2010 = 100) – Germany. 

World Bank (2021b). Exports of goods and services (annual % growth) – Germany.

World Bank (2021c). Medium and high-tech exports (% manufactured exports) – Germany.

World Bank (2021d). GDP growth (annual %) - Italy, United Kingdom, United States, France, Netherlands.

APPENDIX I.

- **OLS procedure** -

The OLS solves:

\[
\min_{\beta_0, \ldots, \beta_k} \sum_{i=1}^{n} (Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_{1i} - \hat{\beta}_2 X_{2i} - \ldots - \hat{\beta}_k X_{ki})^2
\]

Predicted value for individual i in the sample:

\[
\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 X_{1i} + \ldots + \hat{\beta}_k X_{ki}
\]

Residual for individual i in the sample:

\[
\hat{U}_i = Y_i - \hat{Y}_i
\]

The algebraic properties of the OLS regression are the following:

The sum and thus the sample average is equivalent to 0:

\[
\sum_{i=1}^{n} \hat{U}_i = 0
\]

The sample covariance between the regressors and the OLS is zero:

\[
\sum_{i=1}^{n} \hat{U}_i X_{ji}, \ j = 1, \ldots, k
\]

The point \((\bar{x}, \bar{y})\) is always on the regression line

\((\hat{X}_1, \ldots, \hat{X}_k, \bar{Y})\)

The amount of variation to be explained by the regression is the total sum of squares. The formula is the following:

\[
SST = \sum_{i=1}^{n} (Y_i - \bar{Y})^2
\]

The explained sum of squares represents the explained variation. ESS measures the total variation of \(\hat{Y}_1\) from \(\bar{Y}\). The formula is the following:

\[
SSE = \sum_{i=1}^{n} (\hat{Y}_i - \bar{Y})^2
\]

The residual sum of squares represents the unexplained variation. The formula is the following:

\[
SSR = \sum_{i=1}^{n} \hat{U}_i^2
\]

The coefficient of determination is denoted by \(R^2\) and measures the variation of \(Y\) around \(\bar{Y}\). The goodness-of-fit of an OLS regression can be measured as:

\[
R^2 = SSE/SST = 1 - SSR/SST
\]

The Adjusted R-squared is a slightly modified version of \(R^2\), designed to penalize for the excess number of regressors which do not add to the explanatory power of the regression. The Adjusted Coefficient of Multiple Determination can be expressed as follows:

\[
R^2_a = 1 - \frac{SSE/(n-p)}{SSTO/(n-1)} = 1 - \frac{(n-1)SSE}{(n-p)SSTO}
\]
APPENDIX II.
Diagnostic Plot.

![Residuals vs Fitted Diagram]

![Normal Q-Q Plot]

![Scale-Location Plot]

![Residuals vs Leverage Plot]