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The dependencies of subindexes of Stoxx 600 during the Covid-19 pandemic

1. Introduction

The Covid-19 outbreak has been the source of a huge rise in volatility, which has been reflected in financial market turbulence. The values of the distribution of asset returns have increased, intailing a growing risk to financial markets. In addition, the extreme values occur almost simultaneously across asset classes and countries. The rising correlations diminish the positive effects of diversification and finally make financial markets over the world systemically less stable.

A knowledge of the return distribution and risk profiles of stock prices supports channels for profit optimization. Detecting informational inefficiency on financial markets is an important research direction from the point of view of profit maximalization. Stock indexes and subindexes represent an entire stock exchange and particular sectors are used frequently to test for market efficiency.

Most studies on the relationship between indexes use indexes across countries. However, dependencies between subindexes across countries and subindexes and indexes are not frequent topics in the financial literature.

The analysis of the behavior and interrelations between subindexes during the pandemic period will be useful in determining changes in the roles of the major sectors and subsectors of the economy during a time of crisis. This knowledge may be interesting for both individual and institutional investors and may also be

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useful with respect to the potential diversification of their internationally based portfolios as an investment. The lack of a correlation, or only a small correlation, between these subindexes is a very desired property. The consequence is risk reduction arising from portfolio diversification based on these indexed assets.

This empirical study has three aims. Firstly, it aims to find the similarities and dissimilarities in the behavior of subindexes around the beginning of the Covid-19 pandemic. The next topic is the level of dependencies between the subindexes in the time period under consideration. The third aim is to determine the usefulness of the ΔCoVar and MES methodology in this research.

In the next section we provide an overview of selected studies on dependences between subindexes. We use the methodology ΔCoVar, MES and DCC-copulas to assess the relationships between the stock indexes and subindexes under investigation.

2. Literature review

The first papers about the dependence between stock market indexes were published in the 1980's (Higgins, 1988). The authors established whether interrelations are an important source important with respect to forecasting the future level of both stock prices and economic growth of countries. They tried to convince readers that the lack of a weak form of market efficiency is induced by the high level of correlation between the main sector indexes (Arbelaez et al., 2001). Investigations into this problem were begun by Just in 1996 (compare Ratner, 1996). In order to establish the market efficiency of the Madrid Stock Exchange, the author applied nine major indexes from this stock exchange. He detected that the distribution of index returns was non-normal and did not support the random walk hypothesis. In the study by H. Arbeláez et al. (2001), mentioned above, the short-term and long-term interrelations between some stock indexes of the Medellin Stock Exchange (now the Colombia Stock Exchange) are shown. In their comprehensive study, the authors employed a number of procedures and tests of stationarity, including causality, cointegration, impulse response function and variance decomposition and a VEC model based on daily prices over 7 years. They confirmed the existence of a significant interrelation between these indexes.

In the first years of the twenty-first century, some papers on the Athens Stock Exchange (ASE) were published. In their studies M.G. Kavussanos and E. Dockery (2001) came to the conclusion that the Athens Stock Exchange is not efficient in a semi-strong sense.

G.D. Siourounis (2002) used GARCH type models and applied them to the data from the ASE Market. The returns were correlated and their volatility showed autocorrelation. According to Siourinis, the ASE is not weakly efficient. Niarchos and Alexakis (2003) also detected particular price patterns. Due to these patterns, investors can achieve abnormal returns so the ASE is inefficient. Panagiotidis (2005) detected that after the introduction of the Euro the random walk hypothesis was not valid for three different FTSE/ASE indexes.

In a study by T. Patra and S.S. Poshakwale (2008) the subject of research was six sectors of the Athens Stock Exchange: Banking, Industrial, Construction, Insurance, Investment and Holding. These sectors constitute more than 63% of the ASE capitalization. The authors found that the sector indexes are not strongly interrelated in the long term. They found that in the short term the banking sector impacted on the returns and volatility of other sectors. The source of the variance of the returns for most subindexes is their own innovations. The most important banking sector contributed 25% of variance in the construction sector and the insurance sector was responsible for 15% of the variance in the industrial, investment and holding sectors. So, the predominant role was played by the banking sector. Therefore, one can assume that the banking sector may allow at least a short-term prediction of changes in the other sector indexes. The general conclusion is that the ASE did not fulfill the assumptions deriving from the weak efficiency of the market.

The transfer of information between stock markets and regions has also become a popular topic in contributions by many well-known scholars outside Europe and North America. These contributions have also focused on the economies of South Asia and Latin America.

After the global crises of 2008, the imbalances in the global financial and economic system, including emerging markets in different parts of the world, became clear. Besides South Asia and Latin America investors have paid attention to the particular markets of the Middle East and North Africa (Lagoarde-Segot, Lucey, 2008). They are characterized by relatively high returns and volatility, weak interrelations with the largest world markets, and volatility clustering. One of the main aims of T. Lagoarde-Segot and B. Lucey's paper was to detect the level of correlation and the channels of information flow across sectors in these regions. The authors tried to assess the relative importance of the sectors under consideration in their explanation of the variations in returns in these sectors. The second task was to determine information channels across sectors within a stock market (Wang et al., 2005).

In the new situation that has arisen following the outbreak of the Covid-19 pandemic in 2020 and the introduction of many sanitary restrictions in some sectors, the interrelations between indexes and subindexes on an international level are of even greater interest, particularly for policy makers. In our analysis of the linkages between the subindexes of Stoxx Europe 600 index, a methodology known as ΔCoVar is used. This measure of systemic risk was developed by T. Adrian and M.K. Brunnermeier (2011) in order to identify or rank systemically important financial institutions. A recent contribution based on this measure is by M.L. Bianchi and A.M. Sorrentino (2020), who estimate systemic risk for Italian and main European banks. For this purpose, the authors employed the quantile regression and a non-parametric method. G. Girardi and A.T. Ergün (2013) present the results of an estimation of the systemic risk contributions (based on the multivariate GARCH model) of four financial industry groups, including a large number of institutions.

Q. Xu et al. (2018) assess systemic risk in the Chinese banking sector by applying the DCC-MIDAS model with Student's *t* distribution. The multivariate distributions known as copulas (Sklar, 1959) are a useful tool in dependence modeling and risk estimation employed by, among others – Guloksuz and Kumar, 2020; Fabozzi et al. 2013, and Gong et al. 2014.

For dependence evaluation, D.H. Oh and A.J. Patton (2018) suggested a new class of copula-based dynamic models. The factor copulas employed by H. Manner et al. (2021) are considered a tool for modeling high dimensional conditional distributions, helping the estimation of various indicators of systemic risk. This model was applied to a collection of daily CDS (credit default swap) spreads on 100 U.S. firms.

The remainder of this paper is structured as follows. The next section outlines the methodology employed, while the following section describes the dataset and empirical results. The final part of the paper presents some conclusions.

3. Methodology

In this section we briefly quote the dynamic model and systemic risk measures employed in this paper.

3.1. Asymmetric dynamic conditional correlation model

In the literature one can find many models that allow the dependence between time series to be described. The multivariate GARCH belongs to a class of models that allow one to predict second-order moments of returns (see Bauwens et al., 2006 for survey). One of the most popular models in this class is Engle's Dynamic Conditional Correlation (2002), which enables the time varying covariance matrix to be decomposed into standard deviations and a time-varying correlation matrix.

Particular attention has been given to whether changes in the correlation between international asset markets demonstrate evidence of an asymmetric response to negative returns. Taking this into account, L. Cappiello et al. (2006) generalized Engle's to asymmetric cases. We adopt this model along with the bivariate *t* copula, which allows one to describe the tail dependence of the financial time series.

3.2. Systemic risk measurement with ΔCoVar and MES

In this paper we consider two commonly used systemic risks. The first of them is ΔCoVar, which is based on the concept of Value at Risk (Adrian and Brunnermeier, 2011, 2016). Let $\mathbb{C}(r_{st})$ be some event for returns of subindex s. Then ΔCoVar at confidence level α corresponds to the conditional Value at Risk of the market return r_{mt} (main stock index)

$$P\left(r_{mt} \le CoVaR_t^{m|\mathbb{C}(r_{st})} | \mathbb{C}\left(r_{st}\right)\right) = \alpha \tag{1}$$

We consider event $\mathbb{C}(r_{st})$ equal to the Value at Risk of the subindex return at the same level α. The difference between the CoVar at level alpha and CoVar computed in median state is denoted as ΔCoVar (Benoit et al., 2013)

$$\Delta CoVaR_{st}\left(\alpha\right) = CoVaR_t^{m|r_{st}=VaR_{st}(\alpha)} - CoVaR_t^{m|r_{st}=Median(r_{st})} \tag{2}$$

where $VaR_{st}(\alpha)$ satisfies

$$P\left(r_{st} \left\langle VaR_{st}\left(\alpha\right)\right| \mathcal{F}_{t-1}\right) = \alpha \tag{3}$$

where $\mathcal{F}_{t-1}$ is information available up to time $t-1$. $\Delta CoVaR_{st}$ denotes the part of the risk of the market that can be attributed to a given sector.

The second measure that we consider is based on the concept of Expected Shortfall and is defined in (Acharya et al. 2010). The Marginal Expected Shortfall computed at time t (given the information up to time $t-1$) is defined as

$$MES_{st}\left(C\right) = E_{t-1}(r_{st} \mid r_{mt} < C) \tag{4}$$

where the threshold C defines the distress event. MES measures the increase in the risk of the market (expressed by Expected Shortfall of market returns), which is induced by a marginal increase in the weight of sector.

In the literature one can find many methods of computing ΔCoVar and MES. We calculate these measures on the basis of the model by Brownless and Engle (2012)

DCC but replace the bivariate normal distribution with dynamic bivariate t-copula. It can be shown that (see Benoit et al., 2019) ΔCoVar can be expressed as

$$\Delta \text{CoVaR}_{st}(\alpha) = \gamma_{st}\left[VaR_{st}(\alpha) - VaR_{st}(0.5)\right] \tag{5}$$

with $\gamma_{st} = \rho_{st}\sqrt{h_{mt}} / \sqrt{h_{st}}$, where ρ_{st} is a conditional correlation coefficient at time t between market and subindex returns.

During the computation of MES we set the distress event to Value at Risk of the market return $VaR_{mt}(\alpha)$. S. Benoit et al. (2013) showed that in these settings

$$MES_{st}(\alpha) = \beta_{st} ES_{mt}(\alpha) \tag{6}$$

where $\beta_{st} = \rho_{st}\sqrt{h_{st}} / \sqrt{h_{mt}}$, is time-varying conditional β and $E_{mt}(\alpha) = E_{t-1}(r_{mt} \mid r_{mt} < VaR_{mt}(\alpha))$ is the expected shortfall of the market. From this, one can conclude that considering the MES of a sector is the same as considering the beta of a subindex.

Thus, MES measures how the financial institution contributes to the overall risk of the financial system. To summarize, MES takes the returns of a sector into account when the market is in left tail of the return distribution, and ΔCoVar looks at the market when the sector falls in the left tail of the return distribution. The sectors with the highest MES are the greatest drivers of systemic risk (they contribute the most to the decline of the market). The sectors with the highest ΔCoVar make the greatest contribution to market risk. In our approach we consider the absolute values of these measures. Both measures can lead to different conclusions when identifying the least risky and the riskiest sectors. S. Benoit et al. (2013) derived conditions under which rankings based on both measures are convergent. In the empirical part of this paper, we consider the dependence of sectors as well and measure the part of the risk of a given sector that can be attributed to another sector.

4. The data

We consider the daily closing prices of the Stoxx Europe 600 index along with their sectoral indexes in the period 03.01.2018 to 16.04.2021. In Table 1 we present the descriptive statistics of logarithmic returns (in percentages), along with the results of Jarque-Bera and Ljung-Box testing (p-values are reported).

Both the STOXX 600 index and all subindexes are non-normally distributed. The time series of returns are characterized by high kurtosis and negative skewness (in all cases we reject the null of normality). With one exception (Health Care) we also reject the null of lack of autocorrelation (Ljung-Box test).

Table 1

Summary statistics of logarithmic returns

(Sub)index	Mean	S.D.	Kurtosis	Skewness	L-B	J-B
STOXX 600	0.02	1.16	23.56	−1.74	0.00	0.00
Automobiles & Parts	0.01	1.91	17.36	−0.66	0.00	0.00
Banks	−0.04	1.82	14.55	−0.63	0.00	0.00
Basic Resources	0.03	1.89	14.07	−0.44	0.00	0.00
Chemicals	0.03	1.28	10.71	−0.88	0.00	0.00
Construction Materials	0.03	1.49	20.00	−1.47	0.00	0.00
Financial Services	0.04	1.40	22.35	−1.10	0.00	0.00
Food & Beverage	0.01	1.03	14.47	−1.23	0.00	0.00
Health Care	0.03	1.04	12.55	−0.95	0.24	0.00
Industrial Goods Services	0.04	1.42	15.84	−1.04	0.00	0.00
Insurance	0.01	1.57	29.14	−0.97	0.00	0.00
Media	0.02	1.27	16.78	−0.90	0.00	0.00
Oil & Gas	−0.03	1.87	25.42	−1.17	0.00	0.00
Personal Goods	0.02	1.13	11.95	−1.07	0.00	0.00
Real Estate Price	0.00	1.25	22.34	−1.57	0.00	0.00
Retail	0.04	1.20	12.64	−0.86	0.00	0.00
Technology	0.06	1.51	9.89	−0.87	0.00	0.00
Telecommunications	−0.03	1.21	21.73	−0.99	0.00	0.00
Travel & Leisure	0.00	1.82	13.65	−0.37	0.00	0.00
Utilities	0.04	1.25	33.48	−2.58	0.00	0.00

5. Estimation results

In this section we present the results of the estimation of the model presented in subsection 3.1 and compute the dynamic measure of risk from subsection 3.2. In most cases we apply Engle and Ng's Nonlinear Asymmetric GARCH model (1993) to model conditional variances. For the subsectors Insurance and Utilities, the parameter of rotation, at a level of 10%, is not significant. In this case we replace NAGARCH with a basic GARCH model. In Figure 1 we present the conditional variances of all subindexes along with the conditional variance of STOXX Europe 600 (from pair with Automobiles & Parts).

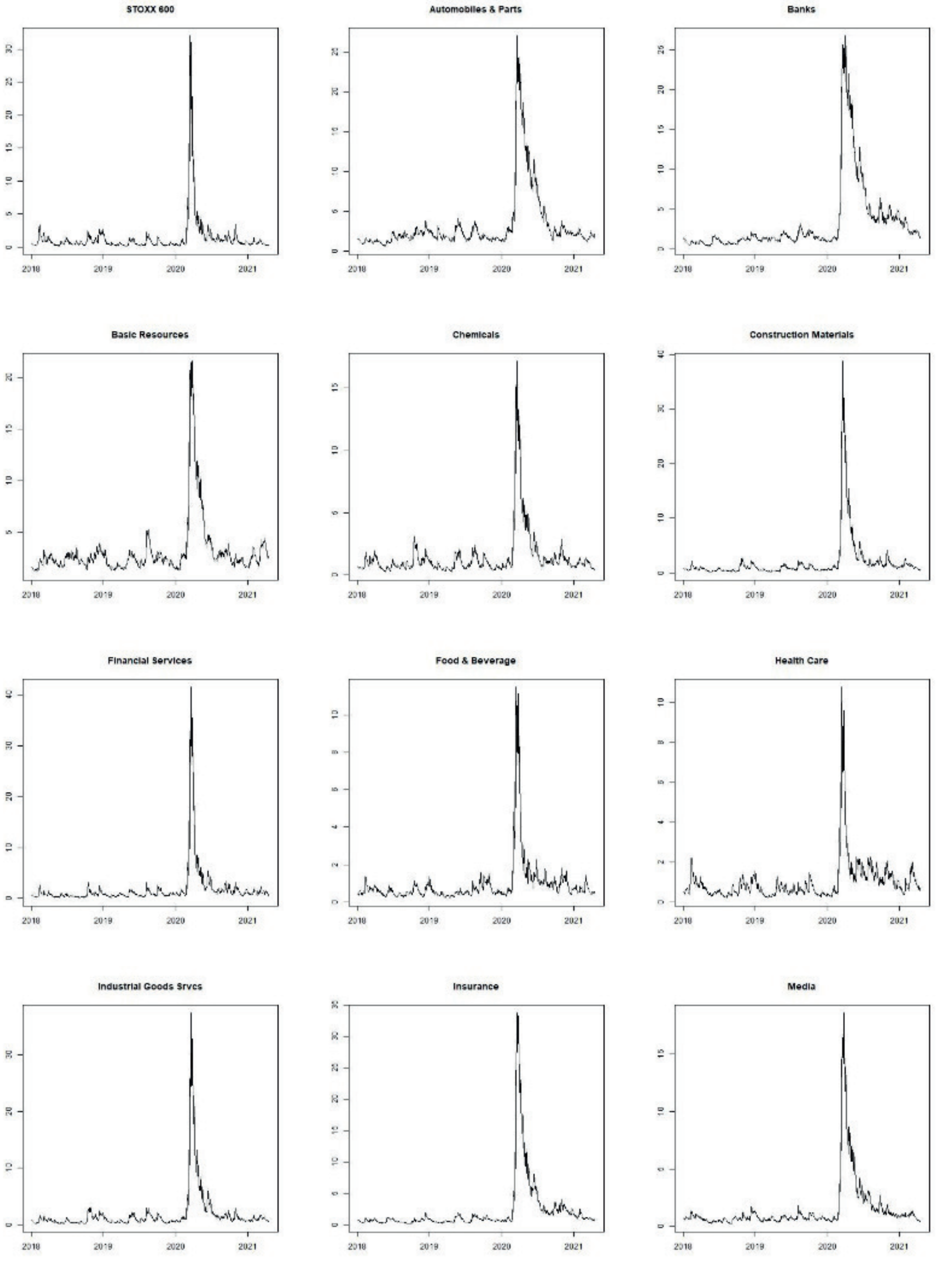

Figure 1. Conditional variances from DCC – copula model

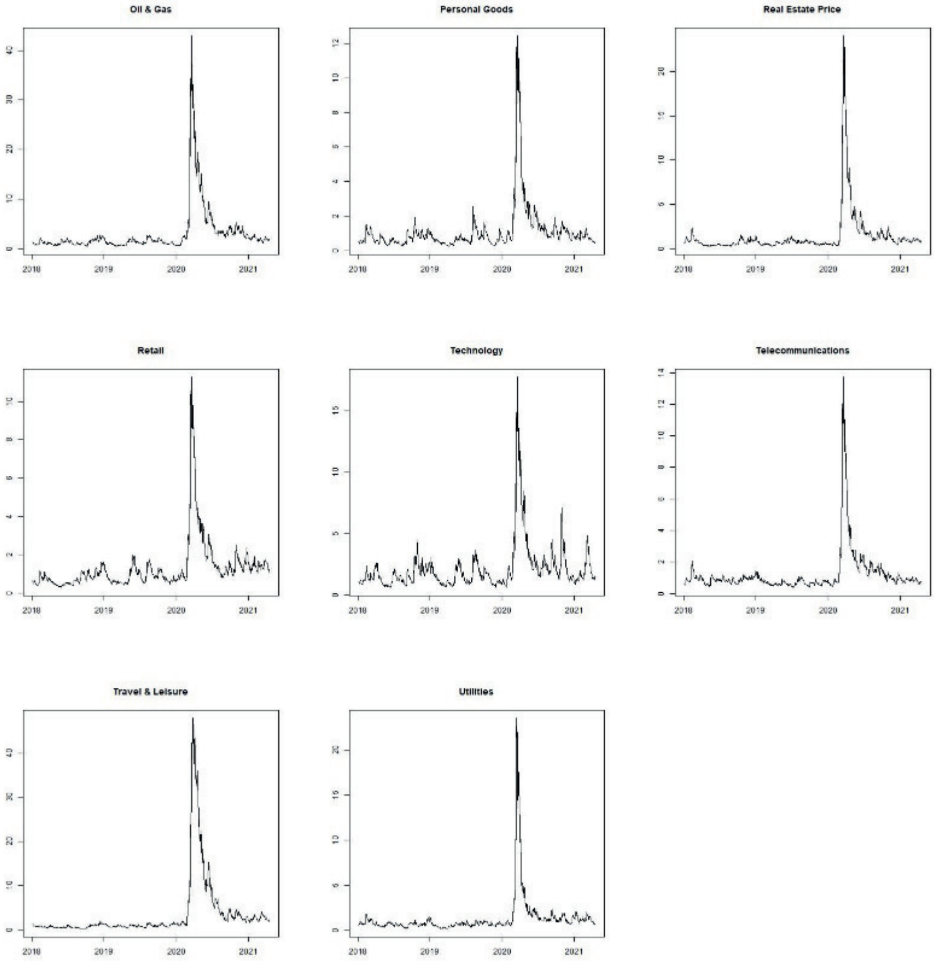

Figure 1. cont.

On the basis of dynamic models, we computed the conditional correlations. For four sectors (Food & Beverage, Health Care, Telecommunications and Travel & Leisure) the parameter of asymmetry, at a level of 10%, was not significant, and we used the standard DCC(1,1) model. Using conditional variances and correlations we compute systemic risk measures in which distress events are Value at Risk at a significance level of 5%. They are presented in Figure 2.

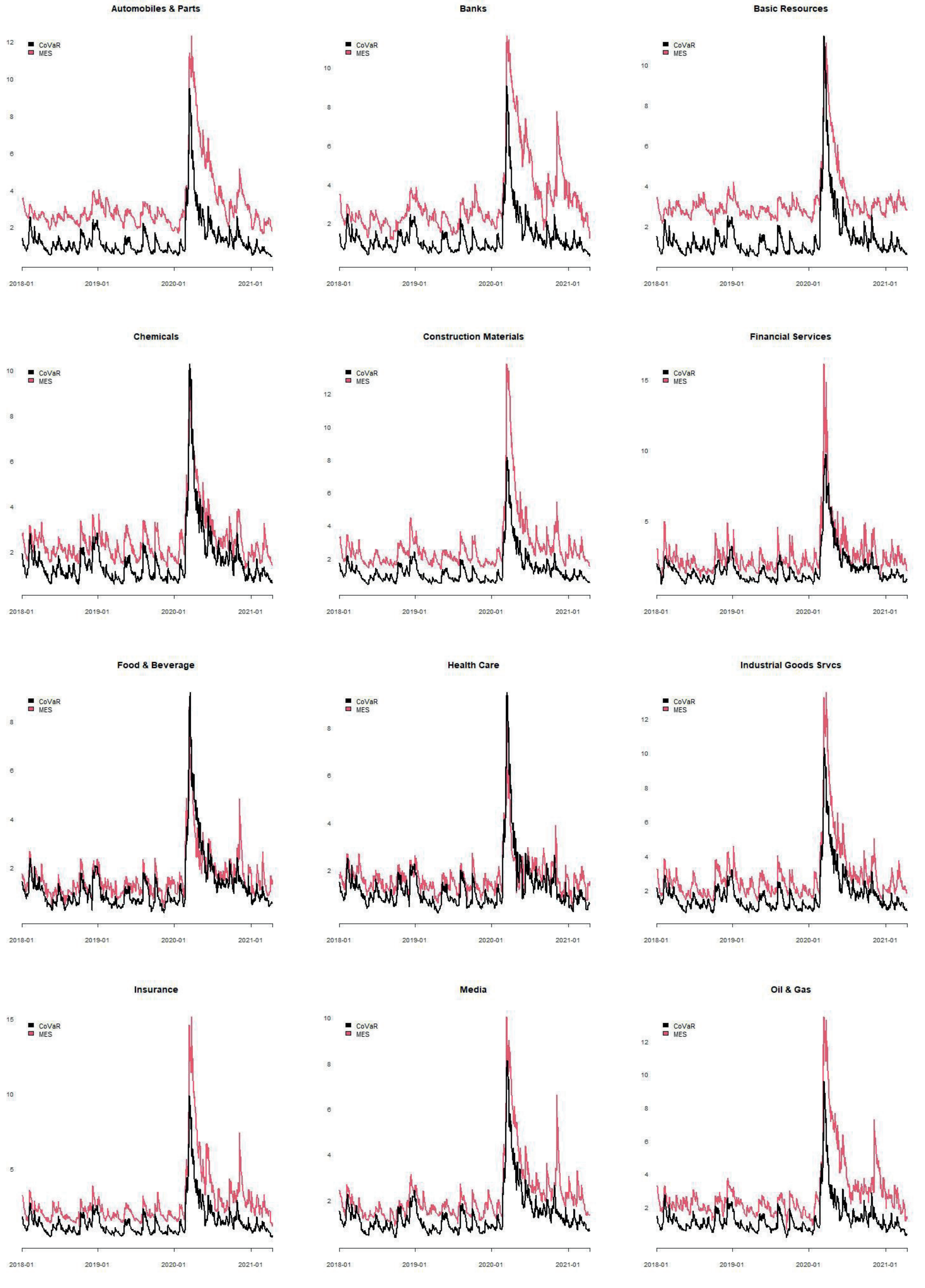

Figure 2. Systemic risk measures from dynamic model

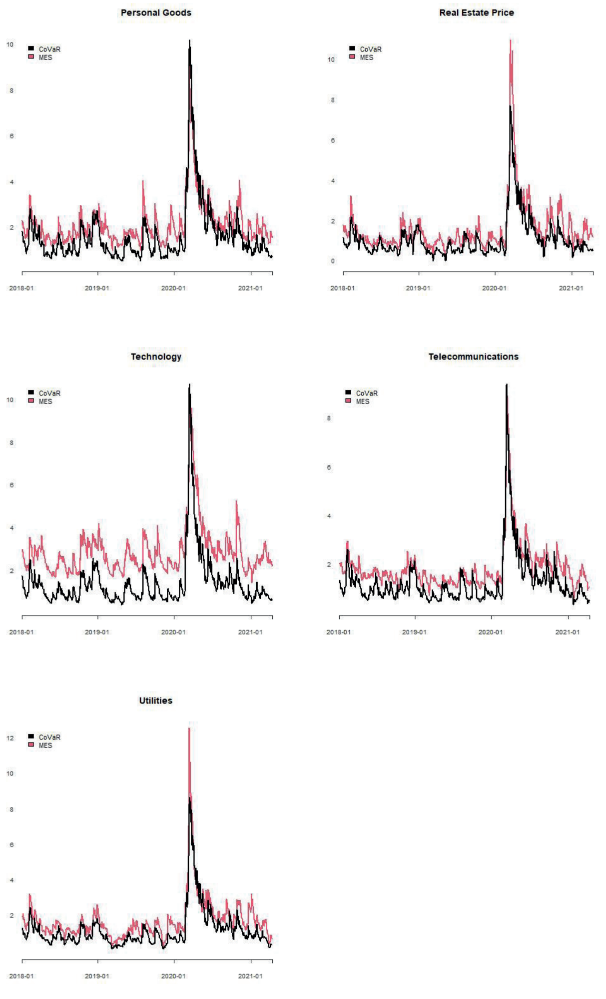

Figure 2. cont.

We observe that the plots of systemic risk measures are very similar and these time series are very strong correlated. The minimum value of Pearson and Spearman correlation coefficients is found for the Travel & Leisure subindex (0.7935) and Basic Resources (0.6367), respectively.

After sorting, we computed the daily percentage of concordant pairs between risk measures. This is illustrated in Figure 3.

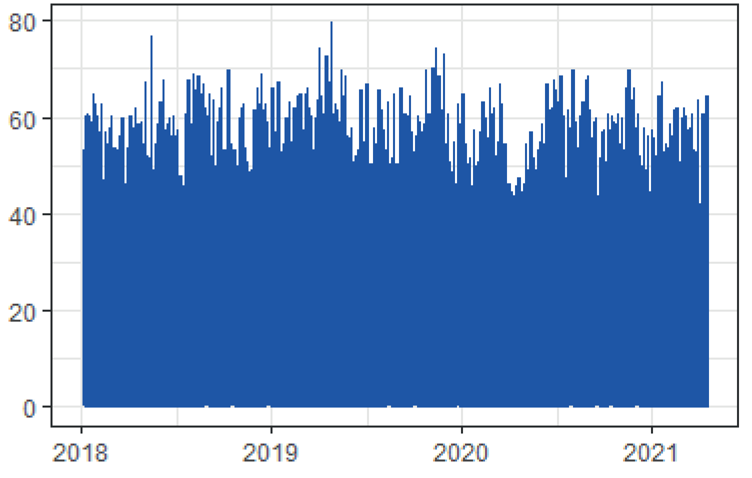

Figure 3. Percentage of concordant pairs between risk measures

On average, for all sectors, the percentage of such pairs is equal to 53.13%. When considering the three riskiest sectors we obtain a value of 51.58%.

To establish whether the rankings produced by systemic risk measures are stable, we computed the Kendall correlation coefficient between the systemic risk ranking obtained on consecutive days. When all 19 subsectors are taken into account, the mean values of correlation coefficient for ΔCoVar and MES are 0.36 and 0.47, respectively. When we consider the three riskiest sectors, we obtain the values 0.44 and 0.52, which indicates poor stability of rankings (the number of days with a perfect positive correlation is equal to 455 and 481, respectively).

It can also be seen that the maximum values of ΔCoVar and MES are noted in similar periods. This is the case for conditional variances as well. In Table 2 we present the dates on which the maximum values of conditional variances and systemic risk measures are observed.

Table 2

Dates of the maximum values of conditional variances and systemic risk measures

Subindex	Variance	ΔCoVar	MES
Automobiles & Parts	25.03.2020	17.03.2020	25.03.2020
Banks	17.03.2020	13.03.2020	17.03.2020
Basic Resources	25.03.2020	13.03.2020	25.03.2020

Table 2 cont.

Chemicals	13.03.2020	17.03.2020	13.03.2020
Construction Materials	17.03.2020	17.03.2020	13.03.2020
Financial Services	13.03.2020	24.03.2020	13.03.2020
Food & Beverage	13.03.2020	19.03.2020	13.03.2020
Health Care	13.03.2020	17.03.2020	13.03.2020
Industrial Goods Services	25.03.2020	17.03.2020	25.03.2020
Insurance	25.03.2020	13.03.2020	25.03.2020
Media	13.03.2020	17.03.2020	13.03.2020
Oil & Gas	25.03.2020	13.03.2020	13.03.2020
Personal Goods	13.03.2020	17.03.2020	13.03.2020
Real Estate Price	17.03.2020	13.03.2020	17.03.2020
Retail	13.03.2020	17.03.2020	13.03.2020
Technology	13.03.2020	17.03.2020	13.03.2020
Telecommunications	18.03.2020	17.03.2020	18.03.2020
Travel & Leisure	25.03.2020	13.03.2020	25.03.2020
Utilities	13.03.2020	17.03.2020	13.03.2020

The most frequent three dates are 13.03.2020, 17.03.2020, 25.03.2020 and it can be easily seen that they are not coincidental with the maximum values of the conditional correlations. Obviously, it is not easy to explain the rapid increase in risk. We noted that on 13 March 2020 the head of the World Health Organization announced that Europe was then the centre of the COVID-19 pandemic, and on 17 March 2020 the coronavirus threat risk in Germany was raised from moderate to high. We noted that the STOXX 600 Europe index decreased on 16 March, along with decreases in its subindexes, but on 17 March 2020 it mostly increased (similary to, for example, the DAX index). On both 24 and 25 March 2020 the STOXX 600 Europe index and subindexes increased (with returns of 8% and 3% of the main index on those days). Regarding the pandemic news, on 25 March 2020 Spain recorded more total deaths than any country except Italy. On 13 March 2020 the riskiest sectors were Basic Resources according to ΔCoVar and Financial Services according to MES, whereas the sectors with the lowest risk were Real Estate Price and Health Care. On 17 March 2020 the situation was analogous. On 25 March 2020 the most and least risky sectors were the same in terms of ΔCoVar, but for MES these sectors were Insurance and Food & Beverage. At the end of our sample, considering ΔCoVar Financial Services turned out the riskiest, whereas Utilities the least. According to MES the riskiest and least risky are Basic Resources and Utilities, respectively.

Wishing to construct rankings of sectors that are characterized by the highest and lowest mean values of systemic risk, we adopt Bai and Perron's test of multiple structural breaks (1998, 2003), in the time series of ΔCoVar and MES.

If $y_t = m_i + \varepsilon_t$ be the series of systemic risk under consideration with mean m_i and error term ε_t for $t = T_{i-1} + 1, T_{i-1} + 2, \dots, T_i$ and $i = 1, 2, \dots, M + 1$. The unknown break dates (or optimal partition) $T_1, T_2, \dots, T_M$ and their number are found using methods of least squares and the Bayesian Information Criterion. Three breakpoints were found for some subindexes, but we only report the dates of breakpoints found during the pandemic period, which are presented in the Table 3.

Table 3

Dates of breakpoints in systemic risk measures

Subindex	ΔCoVar		MES	
Automobiles & Parts	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Banks	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Basic Resources	24.02.2020	20.08.2020	27.01.2020	23.07.2020
Chemicals	24.02.2020	20.08.2020	27.01.2020	23.07.2020
Construction Materials	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Financial Services	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Food & Beverage	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Health Care	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Industrial Goods Services	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Insurance	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Media	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Oil & Gas	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Personal Goods	24.02.2020	20.08.2020	20.02.2020	18.08.2020
Real Estate Price	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Retail	24.02.2020	20.08.2020	20.02.2020	18.08.2020
Technology	24.02.2020	20.08.2020	27.01.2020	23.07.2020
Telecommunications	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Travel & Leisure	24.02.2020	20.08.2020	24.02.2020	20.08.2020
Utilities	24.02.2020	20.08.2020	24.02.2020	20.08.2020

In the case of ΔCoVar breakpoints are found at the same time as on 24.02.2020 (on that day STOXX 600 Europe dropped 3.79% and, for example, DAX dropped about 4%) and 20.08.2020 (because of bad forecasts concerning the prognosis of the U.S. economy published by the Fed at its July FOMC Wall Street meeting, U.S. stock exchanges closed lower than before; additional factors with an impact on stock exchanges were problems and tensions between the United States and China, which reached their culmination on those days). For MES, these dates occur very often.

We divide our sample with these dates and compute the mean values of ΔCoVar and MES and in computing the mean daily values, we rank the sectors. The Tables 4 and 5 present these values in descending order.

Table 4

Ranked mean values of ΔCoVar in subperiods

from 04.01.2018 to 24.02.2020	**from 25.02.2020 to 20.08.2020**	**from 21.09.2020 to 16.04.2021**
Industrial Goods Services	Industrial Goods Services	Industrial Goods Services
Financial Services	Financial Services	Financial Services
Chemicals	Personal Goods	Personal Goods
Personal Goods	Chemicals	Retail
Retail	Retail	Chemicals
Insurance	Basic Resources	Media
Basic Resources	Technology	Insurance
Travel & Leisure	Insurance	Basic Resources
Oil & Gas	Food & Beverage	Food & Beverage
Technology	Media	Oil & Gas
Automobiles & Parts	Automobiles & Parts	Construction Materials
Banks	Utilities	Technology
Media	Health Care	Travel & Leisure
Construction Materials	Banks	Automobiles & Parts
Health Care	Telecommunications	Banks
Telecommunications	Construction Materials	Telecommunications
Food & Beverage	Oil & Gas	Health Care
Utilities	Travel & Leisure	Utilities
Real Estate Price	Real Estate Price	Real Estate Price

Table 5

Ranked mean values of MES in subperiods

from 04.01.2018 to 24.02.2020	**from 25.02.2020 to 20.08.2020**	**from 21.09.2020 to 16.04.2021**
Basic Resources	Travel & Leisure	Banks
Automobiles & Parts	Banks	Oil & Gas
Technology	Automobiles & Parts	Travel & Leisure
Banks	Oil & Gas	Basic Resources
Industrial Goods Services	Insurance	Insurance
Chemicals	Industrial Goods Services	Automobiles & Parts
Construction Materials	Construction Materials	Technology
Financial Services	Basic Resources	Construction Materials
Oil & Gas	Financial Services	Industrial Goods Services
Insurance	Technology	Financial Services
Retail	Media	Media
Personal Goods	Chemicals	Retail
Travel & Leisure	Personal Goods	Chemicals
Media	Utilities	Personal Goods
Telecommunications	Retail	Utilities
Health Care	Real Estate Price	Telecommunications
Food & Beverage	Telecommunications	Food & Beverage
Utilities	Food & Beverage	Health Care
Real Estate Price	Health Care	Real Estate Price

From Table 4 it can be seen that the sectors with the highest and lowest DCoVar are Industrial Goods Services and Real Estate Price, respectively, regardless of the periods. The rankings of MES are very different and there is no clear pattern. In the most critical period, the highest mean value of MES is assigned to the Travel & Leisure (18 place in ranking of ΔCoVar) sector and the lowest to the Health Care (13 place in ranking of ΔCoVar sector. We observe the similarity of rankings before and after this period (Real Estate Price at the bottom of the tables). Regarding the concordance of rankings according to the mean values of systemic risk we note 101 concordant pairs for the full sample (59% of all pairs), whereas for subperiods: 84 (49%), 70 (41%) and 79 (46%).

In Tables 6 and 7 we present the percentage changes of systemic risk measures with respect to the subperiod 04.01.2018 to 24.02.2020.

Table 6

Percentage changes of ΔCoVar

from 24.02.2020 to 20.08.2020		from 16.04.2020 to 16.04.2021	
Utilities	293.18	Utilities	31.46
Real Estate Price	258.38	Food & Beverage	30.99
Food & Beverage	256.13	Media	26.25
Basic Resources	216.95	Real Estate Price	22.83
Telecommunications	207.82	Insurance	15.02
Technology	206.15	Retail	13.39
Media	200.32	Personal Goods	12.66
Personal Goods	198.22	Financial Services	12.56
Health Care	198.07	Telecommunications	12.48
Financial Services	191.77	Construction Materials	11.50
Retail	191.11	Industrial Goods Services	9.35
Automobiles & Parts	189.40	Oil & Gas	8.58
Chemicals	188.25	Basic Resources	7.61
Insurance	186.61	Chemicals	5.55
Construction Materials	184.35	Technology	5.49
Banks	182.50	Health Care	4.89
Industrial Goods Services	170.44	Banks	3.44
Oil & Gas	168.71	Travel & Leisure	3.18
Travel & Leisure	157.96	Automobiles & Parts	3.03

Table 7

Percentage changes of MES

from 24.02.2020 to 20.08.2020		from 20.08.2020 to 16.04.2021	
Travel & Leisure	267.01	Travel & Leisure	69.71
Real Estate Price	199.90	Banks	47.28
Insurance	180.71	Media	44.40
Oil & Gas	179.65	Oil & Gas	42.60
Utilities	177.66	Insurance	39.29
Banks	175.07	Utilities	38.36

Table 7 cont.

from 24.02.2020 to 20.08.2020		from 20.08.2020 to 16.04.2021	
Media	159.14	Real Estate Price	37.36
Construction Materials	146.84	Food & Beverage	32.30
Industrial Goods Services	134.79	Retail	23.21
Automobiles & Parts	134.27	Construction Materials	18.36
Food & Beverage	130.71	Financial Services	17.33
Financial Services	128.05	Telecommunications	13.86
Telecommunications	121.20	Personal Goods	12.54
Personal Goods	97.25	Industrial Goods Services	10.67
Chemicals	93.51	Automobiles & Parts	5.80
Basic Resources	82.89	Technology	5.24
Retail	80.49	Basic Resources	4.90
Health Care	79.51	Health Care	4.81
Technology	77.11	Chemicals	1.20

According to the measure ΔCoVar changes exceed 150% for all sectors in the most critical period and 7 of them exceed 200%, with the Utilities (for both intervals this sector is characterized by the greatest change) sector at the top. In turn, Travel & Leisure is notable for its lowest percentage change, unlike the ranking of changes of MES. The changes in the subperiods of the first and second waves in respect to the pre-pandemic period are the highest for the Travel & Leisure sector. Regarding the bottom of Table 7, we note the Technology sector with a percentage change above 77% and the Chemicals sector with 1.2 % change.

6. Conclusions

With ΔCoVar and MES we can assess systemic risk contributions among financial and insurance institutions. Risk increases in crisis periods and the level of changes is often the subject of interest. Despite the similarity between the time series plots of both measures, the percentage of concordant pairs of daily rankings is on average equal to about 50%. The rankings also indicate poor stability, which is proven by rank correlation between consecutive days. We also note that rankings of the most and least risky sectors are different and depend on the choice of measure. If there is such compliance, it is very rare. Applying the structural breaks estimation method, we found specific dates very similar for all sectors and both measures. Constructing the rankings of sectors in terms of the highest and lowest mean values at specific intervals we also do not obtain compatibility. For both measures we note huge percentage changes in mean risk values, especially in the period from 24.02.2020 till 20.08.2020 compared to the previous period. The percentage changes for both intervals indicate the same riskiest sectors, but the indications of both measures are not consistent.

References

[1] Adrian, T. and Brunnermeier, M.K. (2011) 'CoVaR' NBER Working Paper, No. 17454.

[2] Adrian, T. and Brunnermeier, M.K. (2016) 'CoVaR', *American Economic Review*, vol. 106 (7), pp. 1705–1741.

[3] Arbeláez, H., Urrutia. J. and Abbas, N. (2001) 'Short-term and long-term linkages among the Colombian capital market indexes', *International Review of Financial Analysis*, vol. 10 (3), pp. 237–273.

[4] Bai, J. and Perron, P. (1998) 'Estimating and testing linear models with multiple structural changes', *Econometrica*, vol. 66, pp. 47–78.

[5] Bai, J. and Perron, P. (2003) 'Computation and analysis of multiple structural changes model', *Journal of Applied Econometrics*, vol. 18, pp. 1–22.

[6] Bauwens, L., Laurent, S. and Rombouts, J.V.K. (2006) 'Multivariate GARCH models: A survey', *Journal of Applied Econometrics*, vol. 21(1), pp. 79–109.

[7] Benoit, S., Colletaz, G., Hurlin, C. and Perignon, C. (2013) 'A Theoretical and Empirical Comparison of Systemic Risk Measures', HEC Paris Research Paper No. FIN-2014-1030.

[8] Bianchi, M.L. and Sorrentino, A.M. (2020) 'Measuring CoVaR: An Empirical Comparison', *Computational Economics*, vol. 55, pp. 511–528.

[9] Bollerslev, T. (1990) 'Modelling the coherence in short-run nominal exchange rates: a multivariate generalized ARCH approach', *Review of Economics and Statistics*, vol. 72, pp. 498–505.

[10] Brownlees, C.T. and Engle, R. (2012) 'Volatility, correlation and tails for systemic risk measurement', Available at SSRN, 1611229.

[11] Cappiello, L., Engle R.F. and Sheppard, K. (2006) 'Asymmetric Dynamics in the Correlations of Global Equity and Bond Returns', *Journal of Financial Econometrics*, vol. 4(4), pp. 537–572.

[12] Engle, R.F. (2002) 'Dynamic Conditional Correlation', *Journal of Business and Economic Statistics*, vol. 20(3), pp. 339–350.

[13] Fabozzi, F.J., Stoyanov, S.V. and Svetlozar R.T. (2013) 'Computational aspects of portfolio risk estimation in volatile markets: a survey', *Studies in Nonlinear Dynamics and Econometrics*, vol. 17(1), pp. 103–120.

[14] Girardi, G. and Ergün, A.T. (2013) 'Systemic risk measurement: Multivariate GARCH estimation of CoVaR', *Journal of Banking & Finance*, vol. 37(8) 3169–3180.

[15] Gong, J., Wu, W., McMillan, D. and Shi, D. (2015) 'Non-parametric estimation of copula parameters: testing for time-varying correlation', *Studies in Nonlinear Dynamics & Econometrics*, vol. 19(1), pp. 93–106.

[16] Guloksuz, C.T. and Kumar, P. (2019) 'A new bivariate Archimedean copula with application to the evaluation of VaR', *Studies in Nonlinear Dynamics & Econometrics*, vol. 17(2), pp. 23–36.

[17] Gurgul, H. and Syrek, R. (2014) 'The relationship between WIG-subindexes: evidence from the Warsaw Stock Exchange', *Managerial Economics*, vol. 15(2), pp. 149–164.

[18] Gurgul, H., Mestel, R. and Syrek, R. (2017) 'MIDAS models in banking sector – systemic risk comparison', *Managerial Economics*, vol. 18(2), pp. 165–181.

[19] Higgins, B. (1988) 'Is a recession inevitable this year?', *Economic Review*, vol. 73(1), pp. 3–16.

[20] Kavussanos, M.G. and Dockery, E. (2001) 'A multivariate test for stock market efficiency: the case of ASE', *Applied Financial Economics*, vol. 5, pp. 573–584.

[21] Lagoarde-Segot, T. and Lucey, B. (2008) 'Efficiency in emerging markets--Evidence from the MENA region', *Journal of International Financial Markets*, vol. 18, pp. 94–105.

[22] Manner, H., Stark, F. and Wied, D. (2021) 'A monitoring procedure for detecting structural breaks in factor copula models', *Studies in Nonlinear Dynamics & Econometrics*, vol. 25(4), pp. 171–192.

[23] Niarchos, N.A., Alexakis, C. (2003) 'Intraday stock price patterns in the Greek stock exchange', *Applied Financial Economics*, vol. 13(1), pp. 13–22.

[24] Oh, D.H. and Patton, A.J. (2017) 'Time-Varying Systemic Risk: Evidence From a Dynamic Copula Model of CDS Spreads', *Journal of Business & Economic Statistics*, vol. 36(2), pp. 181–195.

[25] Panagiotidis, T. (2005) 'Market capitalisation and efficiency. Does it matter? Evidence from the Athens stock exchange', *Applied Financial Economics*, vol. 15, pp. 707–713.

[26] Patra, T. and Poshakwale, S.S. (2008) 'Long-run and short-run relationship between the main stock indexes: evidence from the Athens stock exchange', *Applied Financial Economics*, vol. 18, pp. 1401–1410.

[27] Ratner, M. (1996) 'Investigating the behaviour and characteristics of the Madrid stock exchange', *Journal of Banking and Finance*, vol. 20, pp. 135–149

[28] Sheppard, K.K. and Engle, R.F. (2001) 'Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH', NBER Working Paper No. 8554.

[29] Sklar, A. (1959) 'Fonctions de repartition á n dimensions et leurs marges', *Publications de l'Institut Statistique de l'Université de Paris*, vol. 8, pp. 229–231.

[30] Siourounis, G.D. (2002) 'Modelling volatility and test for efficiency in emerging capital markets: the case of the Athens stock exchange', *Applied Financial Economics*, vol. 1, pp. 47–55.

[31] Tse, Y.K. (2000) 'A test for constant correlations in a multivariate GARCH model', *Journal of Econometrics*, vol. 98(1), pp. 107–127.

[32] Tse, Y.K. and Tsui, A.K.C. (2002) 'A multivariate generalized autoregressive conditional heteroscedasticity model with time-varying correlations', *Journal of Business and Economic Statistics*, vol. 20(3), pp. 351–362.

[33] Wang, Z., Kutan, A. and Yang, J. (2005) 'Information flows within and across sectors in Chinese stock markets', *The Quarterly Review of Economics and Finance*, vol. 45, pp. 767–780.

[34] Xu, Q., Chen, L., Jiang, C. and Yuan, J. (2018) 'Measuring Systemic Risk of the Banking Industry in China: A DCC-MIDAS-t Approach', *Pacific-Basin Finance Journal*, vol. 51, pp. 13–31.

Summary

In this index study, the relationships between Stoxx Europe 600 and sector indices are analyzed. This research uses ΔCoVar and MES as analytical tools developed as a measure of systemic risk and applied to financial institutions, to sectoral subindexes. For the sake of systemic risk assessment we calculate the dynamic correlation model with bivariate *t* copula distribution. We focus on the impact of sectors on the market. Despite the similarity between the time series plots of both measures, with maximum values on similar days, the compatibility of daily rankings, measured as a percentage of concordant pairs, is equal to about 50%. The rankings of the most and least risky sectors are different and depend on the choice of measure, but in the case of both we observe poor stability. When sectors are ranked in terms of the highest and lowest mean values at specific intervals (designated by the structural break estimation method, which surpisingly detects very similar dates of structural changes) we draw the same conclusions. For both measures we note huge percentage changes in mean values of risk, especially in the period from February 24, 2020 till August 20, 2020 with respect to the previous period. The percentage changes for both intervals indicate the same most risky sectors, but the indications of both measures are not consistent.

JEL codes: G15, G19

Keywords: *Stoxx Europe 600 index, systemic risk, ΔCoVaR, MES, Covid-19 pandemic*

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The impact of the COVID-19 pandemic on the German banking industry – a critical analysis of regulatory easing for banks

1. Introductory overview

The banking industry has been affected both directly and indirectly by the COVID-19 pandemic, with the level of risk faced by banks depending on both their portfolio orientation and the banks' operating area (Deutsche Bundesbank, 2020). In this context, the indirect effects of the pandemic on banks are of great relevance, since – due to lockdowns – commercial and private customers have suffered considerable financial losses (Deutscher Industrie- und Handelskammertag, 2020). To combat this, the federal government passed a comprehensive package of measures in March 2020 to provide financial support to the affected companies and employees (Bundesfinanzministerium, 2020c). At the beginning of the first lockdown, the national and international supervisory authorities (National Competent Authority – NCA) decided on and implemented a wide range of support measures for banks (BaFin, 2021).

In this paper, we will therefore first outline the main regulatory simplifications for German banks before presenting the overall results of an expert study and formulating recommendations for action.

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2. Regulatory easements due to COVID-19

The COVID-19 pandemic is a new situation, the scale of which is difficult to grasp. The consequences of the pandemic are being felt in all sectors of society and represent yet unknown challenges, both in humanitarian and economic terms. The economic consequences of the pandemic may lead to a significant deterioration of bank portfolios and consequently to a higher number of loan defaults. To mitigate these effects, the federal government has taken various measures together with the banking supervisory authorities (Neisen, Schulte-Mattler, 2020, 35). In the following, however, only the most important measures are presented. In this context, the focus is on the easing of capital buffers and the operational area. The main objective of these measures is to avoid a break-down in the provision of credit.

2.1. CRR Quick Fix

In order to further promote credit provision by banks and mitigate the impact of the COVID-19 pandemic on banks, the European Commission published Regulation (EU) 2020/873 amending the CRR (Capital Requirements Regulation) and CRR II (CRR Quick Fix) on 24 June 2020. This includes temporary measures as well as those brought forward from CRR II (Neisen, Schulte-Mattler, 2020, 35). Among others, the changes include the following aspects:

- The interim arrangements to mitigate the IFRS 9 effects on Common Equity Tier 1 capital according to art. 473a CRR are extended by two years (Regulation (EU) 2019/630, 11–13).
- Banks must hold a minimum amount of capital for loans that is available in the event of restructuring or resolution (prudential backstop). This minimum level is intended to avoid the need for state support measures (Deutsche Bundesbank, 2019).
- The temporary introduction of prudential filters for dealing with unrealised gains and losses on government bond-related financial products (Regulation (EU) 2020/873, 15).
- The possible suspension of the qualitative multiplier used in market risk to determine equity. The daily back-testing for the forecasting quality of the models used is only of limited significance due to the high volatility of markets during the COVID-19 pandemic. Bringing forward the regulations from CRR II on support factors for loans to small and medium-sized enterprises (SMEs) and infrastructure companies.
- Allowing reduced risk weights to be reported for loans backed by pensions or salaries.

- Provisional possibility of not taking into account exposures to central governments in the calculation of the leverage ratio (Regulation (EU) 2020/873, 9, art. 1 no. 4 and art. 9) if, from the BaFin's point of view, there are exceptional circumstances (Regulation (EU) 2020/873 art. 1 no. 4 para. b).
- Early application of the CRR II rules on the treatment of software assets, according to which conservatively valued software assets (Regulation (EU) 2019/876 art. 1 no. 18) do not have to be considered as deductible items in accordance with art. 36 CRR II if their value is preserved in the event of insolvency.

2.2. Easing with an impact on capital

At the beginning of the COVID-19 pandemic, both the European Banking Authority (EBA) and the European central Bank (ECB) used the flexibility contained in their regulations and presented easements in capital requirements (Waschbusch, Kiszka, 2020). The easing is intended to give banks the opportunity to continue to grant loans to their customers, even though the worsening economic situation could mean that more capital could be needed to cover credit risks. According to these regulations, banks are allowed to temporarily reduce their capital buffers, as these were built up specifically for times of crisis (EBA, 2020a). Since the national NCAs were requested to reduce the requirements for the countercyclical capital buffer as part of the measures, the BaFin in Germany has already reduced the existing buffer to 0% with effect from 31st March 2020 (BaFin, 2020a).

The existing capital buffer easements can thus lead to a situation where the banks under the supervision of the German supervisory authorities do not fulfil the combined capital buffer requirements according to § 10i of the German Banking Act (KWG). Since the capital buffers are built up in economically good times to be available in times of crisis to absorb negative developments, this does not result in any grounds for objection for the supervisory authorities. However, the restrictions associated with non-fulfilment, such as the distribution ban for dividends or for variable remuneration components (§ 10i para. 2 KWG), must be considered. In addition, any failure to meet the combined requirements must be reported to the supervisory authority without delay. In the event of a shortfall in the requirements according to § 10i para. 6 KWG, the capital maintenance plan must be prepared in the context of a crisis after consulting the supervisory authorities, and the resulting measures as well as the timetable for implementation must be specified (BaFin, 2020c).

In addition, the possibility was created for banks supervised by the ECB to fulfil the requirements of Pillar 2 of the Basel Regulation (P2R, Pillar 2 Requirements) with capital instruments that are not assigned to the Common Equity Tier

1 capital. This means that the instruments of Additional Equity Tier 1 capital and Equity Tier 2 capital can also be considered at this point. This regulation was meant to come into force in January 2021 with the revision of the CRD V (Capital Requirements Directives) and was brought forward to support the banking industry (ECB, 2020). For less significant institutions (LSI), the use of extended capital instruments was possible in Germany at that time (BaFin, 2020b).

In addition to the possibility of using capital buffers, the European supervisory authorities also established the easing of the liquidity coverage ratio (LCR), by which the requirement for compliance with a ratio of at least 100% in accordance with art. 412 CRR can be undercut. The aim of this easing is, on the one hand, to avoid potential liquidity problems for banks and the associated spill over effects for other institutions and, on the other hand, for the economy as a whole (ECB, 2021). Therefore, falling below the defined ratio does not lead to supervisory measures, but a report is still required according to art. 414 CRR. The information requirements until the quota is met again are to be determined individually. The NCAs may also require additional reports beyond the regular supervisory reports (e.g., daily liquidity reports). For LSIs, the BaFin has stipulated that any further shortfall in 10% steps must be reported to the respective institution's supervisors at the BaFin and the German Central Bank. Based on this, a waiver of daily liquidity reports for LSIs is expected (BaFin, 2021).

The obligation to meet the P2G (Pillar 2 Guidance) and the liquidity coverage ratio will be reintroduced depending on the path of economic development. In its FAQ, the ECB specifies a timeline until the end of 2022 in which banks can operate below the P2R. The liquidity coverage ratio depends on both the individual bank as well as the market development. The ECB plans an obligation to comply with this at the earliest from the end of 2021 (ECB, 2021).

In addition to the possibility of falling short on the overall ratio, there are also simplifications in the calculation of the liquidity coverage ratio. For highly liquid assets in the form of shares, these may not show a loss in value of more than 40% even in a stress case (Delegated Regulation (EU) 2015/61 art. 12 no. 1). During the COVID-19 pandemic, it has so far been shown that shares continue to be highly liquid, even if there are fluctuations in value of more than 40% within 30 days. Therefore, LSIs in Germany currently still have the option of including shares as highly liquid assets in the calculation of the LCR even if the 40% limit is exceeded, if they are assigned to one of the main indices (BaFin, 2021). Furthermore, the liquidity coverage ratio exclusivity criterion for LSIs mentioned in the delegated regulation has been suspended. This stipulates that investment funds are only to be included in highly liquid assets if all special assets of the fund also consist exclusively of highly liquid assets. The relief is particularly relevant for special funds that only have one investor and where the investor sets the investment guidelines himself (single-investor funds). Through this suspension, highly liquid assets in the special assets of a single-investor fund can be included in the liquidity coverage ratio, regardless of whether the fund is invested exclusively in highly liquid assets (BaFin, 2021).

3. Easing in the operational area

3.1. Finalising Basel III

One of the most significant facilitations in the operational area is the postponement of the finalisation of Basel III to 1st January 2023. The new regulations will be implemented among others by the CRR II and the CRD V. The introduction of the extensive changes is associated with a high degree of operational effort for banks. By postponing the finalisation, the introduction phase for the output floor, for example, will be extended. The members of the Basel Committee see the postponement as justified, as the strength of the financial system is not endangered, but the operational burden for the banks can be significantly reduced (BCBS, 2020; Waschbusch, Kiszka, 2020).

3.2. Stress tests

In order to assess the stability of the European banking system and to identify existing risks, the EBA conducts an EU-wide stress test every two years. The participants in the stress test include the largest and most important banks supervised by the ECB. Both the ECB and the NCAs as well as the ESRB (European Systemic Risk Board) are involved in conducting the stress test (EBA, 2021). Due to the COVID-19 pandemic, the test scheduled for 2020 was postponed to 2021 with the aim of reducing the operational burden on banks so that they can focus on their core business activities. To still be provided with up-to-date information, the EBA has requested information on the size of the institutions' credit portfolios and their quality as part of an EU-wide survey (EBA, 2020b). In addition to the EBA stress test, a stress test for the LSIs is carried out in years in which no EU-wide stress test takes place. Thus, the stress test planned for 2021 was also postponed by one year (Waschbusch, Kiszka, 2020; BaFin, 2021).

3.3. Moratoria

The EBA published the Guideline on statutory moratoria and non-statutory moratoria on credit repayments in view of the COVID-19 crisis (EBA/GL/2020/02) at the beginning of April 2020. The reason for the introduction of the guideline is that, due to the measures taken to contain the COVID-19 pandemic, many borrowers are currently unable to meet their payment obligations or will be unable to do so soon. The Euro states have each created their own legal regulations for this purpose to support individuals (Baumstark, Mehring, 2020, 10). In the guideline, the EBA sets out how loan agreements that are subject to a general payment moratorium are to be treated for supervisory purposes. The guideline refers to the application of the definition of default according to art. 178 CRR and the classification as a deferral measure according to art. 47b CRR (EBA/GL/2020/02 para. 6). In order not to qualify as a deferral measure pursuant to art. 47b CRR, the moratorium must meet the criteria of no. 10 of the guideline. It is important that the moratorium is not applied to individual debtors, but to groups of debtors only. The criteria relevant for the assignment to a debtor group are to be defined as broadly as possible, so that the borrower can make use of the moratorium without a prior credit assessment. Another essential criterion is that the moratorium was introduced due to the COVID-19 pandemic (EBA/GL/2020/02 para. 10b, 10f). If a payment moratorium fulfils the criteria mentioned in paragraph 10, the days in default are to be counted in accordance with paragraphs 16 to 18 of the EBA guideline on the application of the definition of default in accordance with article 178 CRR (EBA/GL/2016/07) (EBA/GL/2020/02 para. 13). However, the days affected by the moratorium are not counted as days in default (EBA/GL/2016/07 paras. 16–18, EBA/GL/2020/02 para. 13). Despite the payment moratorium, banks should continue to assess the likelihood of a default according to standard practices so as not to underestimate longer-term risks (EBA/GL/2020/02 para. 14). If institutions use moratoria without a law, this must be reported to the NCAs. The report content is defined in paragraph 17 of the guideline on moratoria. Among other things, it includes the date from which the moratorium is applied, the number of debtors and the sum of the exposure values that fall within the scope of application (EBA/GL/2020/02 para. 17a, c).

3.4. Interaction between the front office and the back office in the credit division

The BaFin provides some simplifications for LSIs at the national level, especially for the operational requirements in the credit division based on the MaRisk. There is often a shortage of staff, especially in small banks, which can lead to bottlenecks due to pandemic-related staff shortages. The MaRisk requirement that a strict separation between front and back office must be maintained in the credit division can have an aggravating effect in this context. To counter this circumstance, the BaFin has given banks the opportunity to soften this strict separation in the event of crisis-related staff shortages. This means that employees can work both in the front and back office to ensure the smooth course of business. Banks that make use of this facilitation are therefore required to adequately consider and manage the potential risks that may occur (BaFin, 2021).

Furthermore, banks can also waive a second vote under certain conditions. However, this only applies to loans issued to existing customers within the framework of a state-guaranteed aid programme to bridge crisis-related difficulties. For these loans, the market vote is sufficient at the time of issuance, whereby the back-office vote must be obtained within three months. If the back office votes negatively on such a loan, appropriate risk-limiting measures must be initiated accordingly (BaFin, 2021).

3.5. Non-performing loans

Due to the COVID-19 pandemic, an increase in non-performing loans is expected. The BaFin considers it to be usual and appropriate for banks to support borrowers who are only experiencing difficulties due to the pandemic. However, applying BTO 1.2.5 para. 3 MaRisk, according to which institutions must obtain a restructuring concept from borrowers if they decide to accompany the restructuring, is currently suspended. Therefore, a loan can currently be granted even if the ability to service the debt is not guaranteed because of the crisis. In this context, the bank must conclude within an internal review that the company is able to survive and that the current difficulties would not have occurred without the pandemic situation (BaFin, 2021).

4. Further facilitations

At the beginning of the crisis, the EBA already called on the ECB and the NCAs to perform their supervisory tasks only within an appropriate framework and to show flexibility whenever possible. At the same time, banking audits were postponed whenever possible (EBA, 2020a). In the meantime, however, these are mostly carried out again in an off-site mode (no on-site audits) (BaFin, 2021).

A measure which did not constitute easing for banks as for their commercial customers was the CovInsAG. Under this act, the obligation to file for insolvency was suspended under certain conditions in order to mitigate the consequences of the pandemic for companies that were particularly affected and to avoid a sharp increase in insolvencies. At the same time, the CovInsAG was intended to ensure banks that lending was also promising during the pandemic, even though a positive prognosis for a going concern was difficult to make (Schluck-Amend, Schwarzer, 2020, 46). However, according to section §1 para. 1 CovInsAG, the suspension of the obligation to file for insolvency was only possible if maturity for insolvency had been reached due to the COVID-19 pandemic and there was a chance that insolvency could be resolved again. Essentially, it could be assumed that the requirements were met if on 31st December 2019 the company was not yet insolvent. The suspension of the obligation to file for insolvency was extended until the end of April 2021. Since 1st January 2021, the obligation to file for insolvency could be suspended if a company was in difficulties due to the crisis but had a chance of survival due to state aid payments. The state aid had to be requested by 28th February 2021 (§ 1 para. 2 and 3 CovInsAG).

For banks, this act was a good way to keep their debtors and support them through the time of crisis. However, granting loans in times of crisis is always associated with increased risks, which may be very difficult to calculate due to this measure. However, this act also offered banks the opportunity to reduce their risk due to a privileged status. The basic prerequisite for this, however, was that the borrower's problems were demonstrably caused by the pandemic and that rehabilitation was not already hopeless at the time a loan was granted. The privileges according to § 2 para. 1 CovInsAG referred primarily to short-term loans to bridge existing difficulties (Schluck-Amend, Schwarzer, 2020, 48–49).

5. Expert study – banking supervisory easements in practice

5.1. Sample and methodological approach

The empirical study is intended to contribute to answering the question regarding the extent to which the measures adopted by the supervisory authorities made it easier for German banks to deal with the effects of the COVID-19 pandemic. Therefore, seven guideline-based interviews were conducted with a total of nine experts. All experts were selected according to their professional background. We sought professionals from the banking industry with at least ten years of experience in an area related to the topic discussed. Moreover, it was important to interview experts from different areas to be able to get a full and diversified perspective on the topic. Therefore, experts from the banking industry, from the supervisory authorities and from academia selected. In this context, it is important to mention that the statements and opinions of the experts are their own and do not necessarily represent the institution in which they are currently employed. An anonymised presentation of the experts can be found in Table 1.

Table 1

Experts – Overview

Expert 1	academic and banking background (internal audit and general bank management)
Expert 2	banking background (bank audit)
Expert 3	banking background (e.g., non-performing loan processing and internal audit)
Expert 4	regulatory background (continuous banking supervision)
Expert 5	regulatory background
Expert 6	regulatory background (was involved in the drafting the facilitations)
Expert 7, expert 8 and expert 9	banking background (internal audit)

All interviews were based on a semi-structured questionnaire to structure the interviews, on the one hand, and to make sure all necessary topics were covered, on the other hand. Six of the interviews were individual interviews, the seventh interview was conducted as a group interview at the request of the three experts questioned. This did not lead to any limitations in the analysis. The interviews took place between 25th January 2021 and 10th February 2021 by telephone or video calls and lasted about one and a half hours each.

To be able to analyse the data collected in the interviews, they were audio-recorded and then transcribed based on the rules of Kuckartz (2018) and Dresing/Pehl (2018). Subsequently, the transcribed interviews were analysed using the qualitative content analysis according to Mayring (2015). The most important results are presented below in a summarised form.

5.2. Presentation and interpretation of the results

The expert study was intended to critically analyse the easing measures for German banks enacted by the supervisory authorities about their applicability and their benefit. Furthermore, the question as to whether the measures can contribute to overcoming the effects of the COVID-19 pandemic was addressed. In this context, some facilitation measures are assessed by the experts as very positive, others as very critical. According to the experts, the main purpose of the rapid introduction of easing measures was to calm the market so that both borrowers and the banks themselves could count on the support of the supervisory authorities during the crisis. There are no special beneficiaries of the facilitation measures, according to the experts, as the different banks can benefit from the adopted measures to different extents depending on their individual situation and the respective business model and focus. However, it must be kept in mind that taking advantage of the facilitation measures often goes hand in hand with being more affected by the crisis. The measures can therefore be understood primarily as a signalling effect both towards the banks and towards the economy.

However, the experts list numerous points of criticism regarding the easing of capital requirements. The basic design of the capital buffer requirements serves to build up capital so that it is available in times of crisis. Consequently, the possibility of falling short on these capital buffers is understandable and reflects their purpose. Nevertheless, it has been shown that in practice, falling short on these capital buffers is associated with further, sometimes costly measures, so that the banks try to avoid it if possible. In the current market situation, in which the effects of the COVID-19 pandemic have not yet been reflected in the balance sheets of the companies and banks, a shortfall is generally to be viewed rather critically, as the effects are regarded as second-round effects by the experts. In other words, banks need a comprehensive capital base to absorb the risks as soon as credit risks occur. If banks start using their capital buffers now, there is a possibility that there will be insufficient capital available to counteract risks when they materialise. At the same time, the use of the free equity components for lending can lead to loans being granted to borrowers with poorer credit scores, which can make the effects even more drastic when risks materialise. However, in practice, the easing of capital buffer requirements has so far not led to an increase in lending to borrowers with poorer credit ratings. The caution of banks in avoiding additional or bad risks is very clear in this context. Thus, the measures do not provide a great benefit at this point, as the risks involved are for the most part difficult to calculate.

The benefit from the easing of capital requirements must also be critically reviewed considering the banks' current earnings situation and their options for raising equity capital. Since the lowering of the capital buffer requirements is a temporary measure and the due date of this facilitation has not yet been determined, the financial planning is associated with high risks for banks. Particularly in the forecast of capital available to the banks and to be held to cover the capital requirements, banks cannot reliably plan for the measures adopted due to the lack of a limit on the duration of the facilitation. Therefore, if a shortfall occurs, banks will have to make up for it by the next forecast date to meet their capital budget requirements. Their tight earnings situation can also cause problems for banks in raising new equity capital. If they take advantage of the easing and reduce their capital buffers, this can lead to a situation in which they are no longer able to meet their capital requirements as soon as the measures have been discontinued. This can then lead to difficulties for the affected banks. Banks using the facilitation measures to avoid a necessary merger for the time being can thus widen their structural problems. The lack of equity capital could also lead to a restriction of business activities, especially in structurally weak regions. The restrictions that come into effect when the capital buffers are undercut can also be an obstacle to raising capital. Especially for cooperative banks that push dividends as an incentive for subscribing to business shares, a ban on distributing dividends can have negative effects.

All in all, the measures to suspend the buffer requirements have a signalling effect on banks and can offer them a safety net, but ultimately their use is associated with high risks, which most banks do not want to take now if they can avoid it. It is particularly important to emphasise, however, that these facilitations do not imply a lowering of the minimum capital requirements. The fundamental capitalisation of the banks remains the same.

Eases in the context of the calculation of own funds are mostly brought forward regulations within the framework of the revision of the CRR and thus to be classified within the framework of the Basel III finalisation. The possibility of backing the P2R with additional Equity Tier1 capital and Tier 2 capital is primarily directed at significant banks. Due to the mix of experts, it is not possible to make a standardised statement at this point. However, it can generally be observed that the capitalisation of significant banks is more limited, which is why this regulation can be an advantage for them. At the same time, the requirements for large banks will be adapted to the regulations that already apply to smaller banks in Germany. The adjustment of the qualifying amounts for loans to small and medium-sized enterprises will only help banks if they also make use of the privileged treatment. For smaller banks which are very well capitalised, the benefit of this privileged crediting is usually less than the associated expense, which is why they do not make use of it. At the same time, it is also questionable whether the political reasons for favouring SMEs correspond to the risk content of such loans.

The facilitations in the operational area are very differentiated in terms of their effects. In particular, the abolition of the separation of front and back office is viewed as being very critically by the experts. Regarding the incidents of fraud that have occurred in the past this is understandable. At the same time, however, this measure can be an opportunity for banks with limited personnel, which struggle with pandemic-related staff shortages. Nevertheless, this measure should only be used in exceptional cases. If banks make use of this regulation, they must be aware of the risks that may arise from it.

When considering operational easements for non-performing loans, the following two aspects must be considered. On the one hand, there is the possibility of waiving a reorganisation report. On the other hand, the suspension of the insolvency obligation also plays a role here. The lack of an obligation to file for insolvency can contribute to companies continuing to be kept artificially alive despite an unsustainable business model. However, the amendments to COVInsAG have reduced this risk, as companies must prove that a positive continuation of the company is possible after taking the requested state support into account (§ 1 para. 1 and 3 COVInsAG).

A measure that can be an advantage for both the borrowers and the bank itself is the general moratorium on payments. Banks whose borrowers and lessees were financially restricted by short time work particularly benefit from this. These deferrals made it possible to bridge short-term liquidity bottlenecks of customers without having to mark the loans as defaulted. At the same time, however, the deferral can also extend a loan that is already no longer sustainable, since the lack of debt service capacity is due to structural problems that are, however, masked by the pandemic. The default marker would thus have allowed for an earlier liquidation and thus also an earlier realisation of the collateral. However, the experts note overall that the payment moratoria have some obstacles regarding their design. Among other things, the deferral of interest payments should be mentioned in this context. Due to these particularities, banks tend to use individual agreements with their customers instead of the possible moratoria. The lack of default identification also means that the supervisory authorities do not gain a comprehensive insight into possibly defaulted loans through the banks' reporting. The risks building up in the banks can then no longer be recognised at an early stage. This problem can be limited by the COVID-19 reporting system, but not eliminated.

The experts agree that the current business models of German banks will continue in the future. This also refers to the threefold structure of the German banking industry (savings banks, cooperative banks, credit banks). At this point, the COVID crisis will not lead to a change in the basic business models, although the way business is conducted and bank portfolios will change as a result of the pandemic. The biggest drivers in this regard are digitalisation as well as the changed attitude of people towards life. Due to the earnings situation being burdened by the persistently low interest rate environment, banks have had to look for new ways to generate/increase earnings even before the pandemic. In the past, many banks did not pay too much attention to the topic of digitalisation, which experts justify with the high supervisory requirements that had to be implemented at the same time and the sometimes-considerable costs incurred in the implementation of digitalisation. However, it should be noted at this point that many banks were still doing so well financially in recent years that they were not forced to proactively address this topic or see any reason to do so. However, the COVID-19 pandemic has given this topic an enormous boost, as both the way of doing business and the way of serving customers are becoming more and more digital. The decreasing income due to the low interest rate environment can be improved either by shifting the business models towards a bigger focus on commission business or by changing the portfolio towards new financing topics (e.g., sustainable investments). In addition to new investment opportunities, banks need to become more efficient, as the measures in digitalisation and further regulatory requirements are accompanied by high costs. Reducing costs (e.g., closing branches), rationalisation and digitalisation investments in a bank's infrastructure as well as the development of new sources of income (e.g. commission business, new products) are the logical consequence.

Despite all the measures implemented, experts see the danger of a new financial crisis. In particular, the expected increase in default rates due to loan defaults, caused for example by business insolvencies, could lead to a crisis in the banking industry. Thus, the benefit of the easing measures also depends on how long it will take to lift the restrictions caused by the pandemic. The existing economic buffers and the banks' reserves can only mitigate the pandemic conditions for a limited period. The pandemic has led to severe cutbacks in many areas of society, some of which have had to be buffered by financial aid from the government. However, the consequences of the pandemic would have been even more severe without government support and would subsequently require further assistance, as unemployment, for example, would increase. This (financial) aid also resulted in an increase in public debt in Germany (Tokarski, Wiedmann, 2021, 1).

The research results clearly show that most German banks – from the experts' point of view – still prefer a cautious approach to using the easing measures. The risks caused using the facilitation measures have so far tended to be rated by the banks as higher than the benefits resulting from the implementation of the measures. The questions of whether the facilitation measures have a benefit for the banks and whether they help them overcome the challenges associated with the pandemic can therefore not be answered in general. The measures are partly criticised because they were introduced at a very early stage of the COVID-19 pandemic and have hardly had any effect to date. In addition, uncertainty is very high due to the lack of a time frame for the validity of the measures when they were implemented.

6. Critical concluding remarks

In addition to the challenges posed by the COVID-19 pandemic, banks also must meet high regulatory requirements stemming from many different supervisory regulations. In particular, the implementation of the final regulations from Basel III are associated with a high implementation effort for many banks.

Especially small banks are confronted with problems in this context, as the new requirements often cause a high need of labour that can hardly be managed with the existing personnel capacities. The high requirements are mainly the result of the last financial and economic crisis of 2007 onwards, which revealed weaknesses in the financial system. To be able to continue to guarantee a functioning financial industry and sufficient provision of credit to private individuals and businesses, the regulatory authorities have decided on and implemented various easing measures in the context of the COVID-19 pandemic.

The facilitations that have been made include extensive measures, which, however, have so far had little effect in the context of day-to-day operations in the banks. For example, the reduction of capital buffers built up for times of crisis is a controversial topic of discussion. Since bank portfolios have hardly been affected by the effects of the crisis so far, these measures cannot yet unfold their full effect. The banks are acting cautiously here to be prepared for possible future credit defaults. The tension between the high regulatory requirements, on the one hand, and the mandate of the government to the banks to grant loans as quickly and flexibly as possible during the pandemic, on the other hand, may lead to an excessive use of easing measures. However, since defaults in their credit portfolios as well as violations of the regulatory requirements for due diligence can lead to increased capital requirements, banks are still cautious about using the facilitations that have been provided regarding capital buffers.

In contrast, the scope regarding operational facilitation is much more extensive. However, the past has demonstrated that, for example, the removal of market and follow-up regulations can lead to high operating losses. The banks must therefore compare the costs of a possible risk with the benefits of the measures taken. The banks' increased need for information is also important in this context. The additional workload that arises can lead to a high burden or even an overload of their back office. The possibility of compensating for crisis-related staff shortages in this context gives the banks security, regardless of the actual use.

Payment moratoria are a good opportunity for banks to help their clients who have experienced liquidity bottlenecks due to the crisis. However, whether the moratoria are more useful and helpful than individually agreed deferral measures remains questionable. In particular, the suspension of default covenants that comes with the deferrals can be a great advantage for banks. At the same time, however, it should be noted that the existing uncertainty about the informative value of the economic documents as well as the suspension of the insolvency obligation make it difficult to recognise actual defaults. This is because the resulting risks in the bank balance sheets can unfold almost completely undetected. Only the COVID-19 reporting system can provide the supervisory authority with an indication of the development in a bank's balance sheet.

As to whether the timing of the introduction of the facilitations was reasonable or not is difficult to answer at this point, as comparable situations have not yet occurred in the past. Generally, the measures are to be seen as a step in the right direction. At the same time, however, they can also pose a great risk. This is especially true if the use of the measures means that already existing structural problems of a bank continue to remain undetected and thus possibly worsen undetectably.

These measures do have a signalling effect on the financial industry. However, the extent to which the measures can mitigate the full effects of the crisis once they are felt in the balance sheets of companies and once there are more defaults in the future cannot be conclusively clarified at this point. Fortunately, due to government assistance and well-positioned companies, only a few borrowers have been negatively affected so far. However, due to the measures of payment moratoria and the resulting removal of the assignment to default status, it is currently unclear how high the actual risks are. The caution that banks are currently exercising in taking advantage of the measures, however, speaks for a predominantly good risk management. Especially with regard to their equity capital, the banks have been able to build up sufficient capital buffers in recent years, so that in most cases it is currently not necessary to fall short on the capital buffer requirements.

If the massive increase in risk provisioning forecast occurs, a reduction of the capital situation in the entire banking industry must be expected to be able to cover the resulting defaults. It is therefore important that the measures will still be valid at this time, so that their intended effect can fully unfold.

References

[1] BaFin (2020a) Allgemeinverfügung zur Herabsetzung der Quote des inländischen antizyklischen Kapitalpuffers [Online], Available: https://www.bafin.de/SharedDocs/Veroeffentlichungen/DE/Aufsichtsrecht/Verfuegung/vf_200331_allgvfg_antizykl_kapitalpuf fer.html;jsessionid=CA8AD07BF99F-7CA265E553CD4B1EAD14.1_cid500?nn=7852116 [7 Mar 2022].

[2] BaFin (2020b) BaFin Journal März 2020 [Online], Available: https://www. bafin.de/SharedDocs/Downloads/DE/BaFinJournal/2020/bj_2003.html [07 Mar 2022].

[3] BaFin (2020c) Einheitlicher Bankenaufsichtsmechanismus – SSM [Online], Available: https://www.bafin.de/DE/Aufsicht/BankenFinanzdienstleister/EU-Bankenaufsicht/SSM/ssm_node.html#:~:text=Der%20einheitliche%20europ%C3%A4ische%20Aufsichtsmechanismus%20(Single,Aufsichtsbeh%C3%B6rden%20der%20Euro%2DL%C3%A4nder%20zusammen [7 Mar 2022].

[4] BaFin (2021) COVID-19-Lage: Neue Entwicklungen und wichtige Informationen der BaFin [Online], Available: https://www.bafin.de/DE/Aufsicht/CoronaVirus/CoronaVirus_node.html [7 Mar 2022].
[5] Baumstark, N. and Mehring, S. (2020) 'Stundungen im Kreditgeschäft: und ihre Folgen in Zeiten der Corona-Pandemie', Zeitschrift für das gesamte Kreditwesen, vol. 73, pp. 10–14.
[6] BCBS (2020) Governors and Heads of Supervision announce deferral of Basel III implementation to increase operational capacity of banks and supervisors to respond to COVID-19 [Online], Available: https://www.bis.org/press/p200327.htm [7 Mar 2022].
[7] Bundesfinanzministerium (2020a) 50 Milliarden Euro Soforthilfen für kleine Unternehmen auf den Weg gebracht [Online], Available: https://www.bundesfinanzministerium.de/Content/DE/Pressemitteilungen/Finanzpolitik/2020/03/2020-03-23-pm-gemeinsame-PM.html [7 Mar 2022].
[8] Bundesfinanzministerium (2020b) Bundesregierung aktiviert Wirtschaftsstabilisierungsfonds – Massive Bundeshilfen zum Schutz von Unternehmen und Arbeitsplätzen [Online], Available: https://www.bundesfinanzministerium.de/Content/DE/Pressemitteilungen/Finanzpolitik/2020/03/2020-03-23-pm-Wirtschaftsstabilisierungsfond.html [7 Mar 2022].
[9] Bundesfinanzministerium (2020c) Kampf gegen Corona: Größtes Hilfspaket in der Geschichte Deutschlands [Online], Available: https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Schlaglichter/Corona-Schutzschild/2020-03-13-Milliarden-Schutzschild-fuer-Deutschland.html [7 Mar 2022].
[10] Bundesfinanzministerium (2021) Steuerliche Hilfen für Unternehmen und Beschäftigte [Online], Available: https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Schlaglichter/Corona-Schutzschild/2020-03-19-steuerliche-Massnahmen.html [7 Mar 2022].
[11] Deutsche Bundesbank (2019) Monatsbericht – Juni 2019 [Online], Available: https:// www.bundesbank.de/de/publikationen/berichte/monatsberichte/monatsbericht-juni-2019-798776 [7 Mar 2022].
[12] Deutsche Bundesbank (2020) Bankaufsichtliche und regulatorische Herausforderungen in Zeiten von COVID-19 [Online], Available: https://www.bundesbank.de/de/presse/reden/bankaufsichtliche-und-regulatorische-herausforderungen-in-zeiten-von-COVID-19-845288 [7 Mar 2022].
[13] Deutscher Industrie- und Handelskammertag (2020) Auswirkungen von COVID-19 auf die deutsche Wirtschaft [Online], Available: https://www.dihk.de/resource/blob/33776/520f2d184cf1abdda6872835f463fe73/blitzumfrage-corona-nr-5-data.pdf [7 Mar 2022].
[14] Dresing, T. and Pehl, T. (2018) Praxisbuch Transkription: Regelsysteme, Software und praktische Anleitungen für qualitative ForscherInnen, 8th ed., Marburg: Eigenverlag.

[15] EBA (2020a) EBA Statement on actions to mitigate the impact of COVID-19 on the EU banking sector [Online], Available: https://www.eba.europa.eu/sites/default/documents/files/document_library/General%20Pages/Coronavirus/EBA%20Statement%20on%20Coronavirus.pdf [7 Mar 2022].
[16] EBA (2020b) Governance Structure [Online], Available: https://www.eba.europa.eu/about-us/organisation [7 Mar 2022].
[17] EBA (2021) EU-wide stress testing [Online], Available: https://www.eba.europa.eu/risk-analysis-and-data/eu-wide-stress-testing [7 Mar 2022].
[18] ECB (2020) ECB Banking Supervision provides temporary capital and operational relief in reaction to coronavirus [Online], Available: https://www.ecb.europa.eu/press/pr/date/2020/html/ecb.pr200312~45417d8643.en.html [7 Mar 2022].
[19] ECB (2021) Bankenunion [Online], Available: https://www.bankingsupervision.europa.eu/about/bankingunion/html/index.de.html [7 Mar 2022].
[20] Kuckartz, U. (2018) Qualitative Inhaltsanalyse: Methoden, Praxis, Computerunterstützung, 4th ed., Weinheim, Basel: Beltz Verlag.
[21] Mayring, P. (2015) Qualitative Inhaltsanalyse: Grundlagen und Techniken, 12th ed., Weinheim/Basel: Beltz Verlag.
[22] Neisen, M. and Schulte-Mattler, H. (2020) 'Maßnahmen zur Beschränkung der COVID-19-Folgen für Institute', *Die Bank*, pp. 34–41.
[23] Schluck-Amend, A. and Schwarzer, A. (2020) 'CovInsAG – Auswirkungen für Banken', *Zeitschrift für das gesamte Kreditwesen*, vol. 73, pp. 46–50.
[24] Smid, S. (2020) 'Zu den Regelungen des COVID-19-Insolvenzaussetzungsgesetzes (CovInsAG)', *Deutsche Zeitschrift für Wirtschafts- und Insolvenzrecht*, vol. 30, pp. 251–262.
[25] Tokarski, P. and Wiedmann, A. (2021) Das Corona-Schuldenproblem in der Eurozone [Online], Available: https://www.ssoar.info/ssoar/bitstream/handle/document/72543/ssoar-2021-tokarski_et_al-Das_Corona-Schuldenproblem_in_der_Eurozone.pdf?sequence=1&isAllowed=y&lnkname=ssoar-2021-tokarski_et_al-Das_Corona-Schuldenproblem_in_der_Eurozone.pdf [7 Mar 2022].
[26] Waschbusch, G. and Kiszka, S. (2020) Die bremsende Wirkung der Coronakrise auf die finale Umsetzung der Krisenregularien von Banken [Online], Available: https://www.tax-legal-excellence.com/bremsende-wirkung-coronakrise-auf-finale-umsetzung-krisenregularien-banken/ [7 Mar 2022].

Summary

The COVID-19 pandemic was a challenge for all aspects of life. Besides others, this includes health and social life as well as the overall state of the economy. To contain the spread of the coronavirus, governments throughout the world imposed temporary closures (lockdowns). The banking industry was affected by these lockdowns in multiple ways. To mitigate the potential negative impact of the COVID-19 pandemic on banks, the national and international supervisory authorities passed comprehensive measures. The aim of this paper is to highlight the main regulatory facilitations for German banks by focussing on measures regarding capital buffers and the operating areas of banks. Besides this, an expert study was conducted to analyse how the measures are perceived by German banks and to develop recommendations for action. The results of the study show that the measures have mainly had a signalling effect on banks. However, measures like the easing of capital requirements are also related to higher risks for the banks. The results illustrate that most banks have hesitated in taking these additional risks if they can avoid them, with other measures like general moratoria on payments considered helpful. Overall, the results demonstrated that the experts prefer a cautious approach to using the easing measures.

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Forecasting the economic impact of a vacuum tube high-speed transport system in Poland: An input-output approach

1. Introduction

Numerous studies have investigated the impact of infrastructure on the economy (Holmgren, Merkel, 2017). The findings suggest that infrastructure has a positive impact on economic growth (Khan et al., 2020). In particular, infrastructure lowers the cost of the input factors of the production process (Agénor, Moreno-Dodson, 2006) and affects both employment and economic growth (Bristow, Nellthorp, 2000). Additionally, infrastructure enhances the quality of life of a society (Baldwin, Dixon, 2008).

Investments in transport infrastructure have also been investigated. Cigu et al. (2019) argued the unidirectional long-run causality relationship among growth, transport infrastructure, and public sector performance in the EU-28 countries. In a similar line, Gherghina et al. (2018) found that road, inland waterway, maritime, and air transport infrastructures positively influenced the gross domestic product per capita (GDPC) in the EU-28 countries during the period of 1990–2016. Meersman and Nazemzadeh (2017) reported that the lengths of motorways, the

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rail network, and investments in the port infrastructure had a positive impact on Belgium's GDP per capita. The contribution of the transport infrastructure to regional economic growth could also be observed in Korea during the period of 2000–2010 (Lee, Yoo, 2016) as well as China during the period of 2007–2015 (Ke et al., 2020). Mentolio and Solé-Ollé (2009) reported that public investment in the transport infrastructure positively affects the productivity of a region. According to Zou et al. (2008), public investment in road construction in poor areas significantly impact growth and poverty alleviation. The relationship between a transport infrastructure and economic development can be observed in developing countries as well. Based on studies that were undertaken in Sub-Saharan and South Asian countries, Quium (2019) argued that the development of transport infrastructures can have significant positive impacts on economic growth as well as on poverty alleviation, employment, equity, and inclusion. In their long-term studies (including the period of 1971–2017), Alam et al. (2020) found a long-running and causal relationship between transport infrastructure and economic development in Pakistan. Myszczyszyn and Mickiewicz (2020) investigated Germany's economic growth between 1872 and 1913; they found that railways had positively affected economic growth; in parallel, high economic growth influenced the development of transport.

In Poland, a significant development in the transport infrastructure is planned. In particular, the development of a rail network that links the newly planned airport (the Solidarity Transport Hub, which is located in the central part of Poland) with the largest cities around the country (Stryhunivska et al., 2020). One of the considered technologies is a vacuum tube high-speed train (known as a Hyperloop) (Białas et al., 2020). The main element of this concept is a tube that contains air at a reduced pressure (close to a vacuum). The vehicles moving inside the tube can reach speeds of 1,200 km/h. The vacuum tube high-speed train technology would enable the journey time to be shortened; for example, a journey between Stockholm and Helsinki (ca. 500 km) would take approximately 28 minutes (KPMG, 2016). The Hyperloop is a promising idea that aspires to become the "fifth mode of transport" (the other modes are cars, planes, trains, and ships) that can be used in both passenger and cargo transport. However, this innovative means of transportation is at its early stage of development. The existing solutions (including tubes) are prototypes that are designed to test the proposed solutions. To date, several feasibility studies have been published around the world (for example, these pertain to projects in the United States [in the Great Lakes region as well as in California], the UAE [Abu Dhabi], and China [Tongren]). Among these, there is one that refers to Central Europe (that analyzes transportation issues that are related to potential routes linking Vienna, Bratislava, Budapest, Brno, Linz, and Graz [Schodl et al., 2018]). Additionally, the determinants of vacuum tube high-speed train development in Poland have been analyzed with technology roadmapping (Duda et al., 2021). Despite the many unanswered questions related to the Hyperloop technology, it is obvious that the Hyperloop infrastructure (in particular, the tubes) will require extraordinary investments. Among the questions associated with Hyperloop infrastructure investment decisions are the following:

– What will be the impact of a Hyperloop investment on a country's economy?
– Which tube technology (tunnels versus trestles) will impact the economy to a greater extent?
– Which particular industries will benefit the most from the investments (in total, and dependent on the construction technology)?

The impact of high-speed rail (HSR) on the development of an economy and society has been the subject of numerous studies (e.g., Diao, 2018; Yu et al., 2018; Chen, 2019). These studies pertain to regional development (e.g., Li et al., 2020), strengthening social cohesion (e.g., Naranjo Gómez, 2016), and the growth of the tourism industry (e.g., Yin et al., 2019). The negative impact of HSR on the environment is also indicated, along with the methods of its reduction (e.g., Chang et al., 2018). Wang et al. (2018) found that the introduction of HSR leads to a significant increase in city-level housing prices. Hromadka et al. (2020) presented annual impacts of the subcategories of HSR infrastructure (such as railway stations) in the socio-economic context.

To assess the impact of HSR, researchers employ different tools and methods. These include a dynamic and spatial computable general equilibrium (CGE) modeling framework (Chen, 2019), an aggregate growth-modeling and causality test (Meersman, Nazemzadeh, 2017), a Granger causality test (Alam et al., 2020), the auto regressive distributed lag (ARDL) (Muvawala et al., 2020) and vector-autoregressive models (VAR), which include the error correction model (ECM) and long-term relationship research (Myszczyszyn, Mickiewicz, 2020), and a sensitivity analysis (to estimate the efficiency and quality of the HRS services) (Moyano et al., 2019). To identify the associations among the highway and railway transports and the regional economy, Sun et al. (2018) employed the Lotka-Volterra model. Hromadka et al. (2020) used the cost-benefit analysis method to evaluate the socioeconomic impacts of occurrences that emerge from a railway infrastructure.

The aim of this paper is to specify the multiplier effects that are induced in the national economy in reference to the construction of Hyperloop lines in Poland using tunnel and trestle technology. In particular, we calculate the added value and employment growth for several industries that will contribute to the construction process. Additionally, this paper intends to indicate those industries that would benefit the most as well as the construction technology (tunnels versus viaducts) that would have the greatest impact on the economy. We employ an input-output (IO) analysis and the study is based on detailed data from 77 industrial sectors. The scope of the study, its methodology, and the results made this study original in the Polish context as well as for Central Eastern Europe; such a study (investigating the impact of a Hyperloop on the economy) is among the first attempts in this part of Europe. This study offers theoretical and managerial implications.

The remainder of the paper is as follows. First, the methodology for calculating the multiplier effects is presented. Second, possible routes are described, along with their accompanying costs. Third, the results are showed and discussed. Finally, the study's implications and limitations are discussed, and recommendations for future studies are proposed.

2. Calculating multiplier effects

In order to determine the possible multiplier effects in the Polish economy that will likely result from the construction of a new transport connection using Hyperloop technology, three types of input-output (IO) multipliers were calculated by using the linear static demand-driven Leontief IO model (Lach, 2020). In addition to computable general equilibrium (CGE) modeling, IO analysis remains a leading tool that was used in previous reports on the analysis of the economic effects of high-speed railway construction in other countries (Lee et al., 2018).

From a formal point of view, IO multipliers can be understood as interindustry multipliers. In general, such multipliers describe the sectoral impact of changing a particular economic category in one branch on all of the other branches in an economy (Tomaszewicz, 1983; Przybyliński, 2012). This idea often supports the economic policies of governments, as it allows for testing the direct and indirect sectoral impact of stimulating specific branches or making particular investments (e.g., the construction of a new factory will also increase the number of jobs in the factory's suppliers, increase the demand on particular services, etc.). Although 70 years have passed since the Leontief IO model was formulated, its modifications and extensions are still emerging; the applicability and interpretation of IO multipliers continues to be the subject of a lively scientific debate (Lach, 2020).

The empirical calculations that were carried out for this study were based on the assumption that the structure of the interindustry links in the Polish economy is described by the most recent input-output table at basic prices for domestic output that were published in 2019 by the Central Statistical Office of Poland (CSO)[1]. This table gives the possibility of calculating material cost coefficients

[1] The most recent IO table is based on 2015 data – for details, visit https://stat.gov.pl/en/topics/national-accounts/annual-national-accounts/input-output-table-at-basic-prices-in-2015,5,3.html.

that express the share of the costs of domestic raw materials and materials in the overall production costs of the products that are manufactured in the country.

In the further parts of this paper, we will follow the usual notation in the IO literature; therefore, the matrices will be indicated by bold capital letters, the vectors by bold lowercase letters, and the scalars by italicized capital and lowercase letters. Transposition will be indicated by a prime symbol, and a circumflex will denote a diagonal matrix (for example, $\hat{\mathbf{x}}$ has elements of vector $\mathbf{x}$ on the main diagonal, and $\hat{\mathbf{x}}^{-1}$ denotes a diagonal matrix with the inverses of the elements of nonzero vector $\mathbf{x}$ on the main diagonal).

Before deriving the basic linear form of the static Leontief model, one should recall the typical setting and assume that the economy under study consists of n productive sectors and that the respective data is available for year t. Let x_i^t also denote the output of sector i and f_i^t stand for the total final demand for sector i's product for period t[2]. Under this notation one may write a basic balance condition that explains the distribution of sector i's product through sales to all sectors in the economy and to final demand (Miller and Blair, 2009; Lach, 2020)

$$x_i^t = z_{i1}^t + \ldots + z_{in}^t + f_i^t = \sum_{j=1}^{n} z_{ij}^t + f_i^t \tag{1}$$

where z_{ij}^t represents the value of the flow of goods and services that were produced in sector i in the economy under study and consumed in sector j during year t.

After combining the accounting formulas in (1) across all sectors, one can obtain the following compact matrix formula

$$\mathbf{x}_t = \mathbf{Z}_t \mathbf{i} + \mathbf{f}_t \tag{2}$$

where

$$\mathbf{x}_t = \begin{bmatrix} x_1^t \\ \vdots \\ x_n^t \end{bmatrix}, \mathbf{Z}_t = \begin{bmatrix} z_{11}^t & \cdots & z_{1n}^t \\ \vdots & \ddots & \vdots \\ z_{n1}^t & \cdots & z_{nn}^t \end{bmatrix}, \mathbf{f}_t = \begin{bmatrix} f_1^t \\ \vdots \\ f_n^t \end{bmatrix} \tag{3}$$

and $\mathbf{i}$ denotes an $n \times 1$ vector of 1's[3]. Static IO analysis is based on the fundamental assumption that the interindustry flows from sector i to sector j during period t depend entirely on the output of sector j for the same time period. This

[2] Throughout this paper, we will use the terms 'period' and 'year' interchangeably to denote the time interval of interest.

[3] For each sector i, final demand f_i^t is the sum of the final consumption expenditure by households, the final consumption expenditure by non-profit organizations serving households (NPISH), the final consumption expenditure by the government, the gross fixed capital formation, and the changes in inventories and valuables.

assumption makes room for deriving the following definition of the so-called 'technical coefficients' (Miller and Blair, 2009; Lach, 2020)[4]

$$a_{ij}^t = \frac{z_{ij}^t}{x_j^t} \tag{4}$$

where $i, j = 1,...,n$. The coefficients given in (4) measure the fixed relationships between a sector's *j* output and its inputs. Thus, production in a Leontief system operates under what is known as constant returns to scale, as the economies of scale in production are ignored (Miller and Blair, 2009). For example, if sector *i* stands for a sector of services and sector *j* stands for the automotive sector, a_{ij}^t represents the ratio of the value of the services bought by automotive producers during year *t* to the value of the automotive production of year *t* (Lach, 2020).

After combining the technical coefficients that are defined in (5) across all possible flows in an *n*-sector economy, one can obtain the following matrix formula

$$\mathbf{A}_t = \mathbf{Z}_t \hat{\mathbf{x}}_t^{-1} \tag{5}$$

where

$$\hat{\mathbf{x}}_t = \begin{bmatrix} x_1^t & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & x_n^t \end{bmatrix}, \mathbf{A}_t = \begin{bmatrix} a_{11}^t & \cdots & a_{1n}^t \\ \vdots & \ddots & \vdots \\ a_{n1}^t & \cdots & a_{nn}^t \end{bmatrix} \tag{6}$$

The usual terminology in the IO literature is to interchangeably refer to matrix $\mathbf{A}_t$ as the 'input matrix' or 'technology matrix.' Using (5), we may rewrite the set of accounting relationships in (2) in the following form

$$\mathbf{x}_t = \mathbf{A}_t \mathbf{x}_t + \mathbf{f}_t \tag{7}$$

or equivalently

$$(\mathbf{I} - \mathbf{A}_t)\mathbf{x}_t = \mathbf{f}_t \tag{8}$$

where **I** is an $n \times n$ identity matrix. The Leontief model given in (7) allows one to explicitly study the dependence of the interindustry flows on the outputs of each sector.

However, a different question is usually the case in practical applications of the static Leontief model; i.e., given the forecasts of the demands of the exogenous sectors ($\mathbf{f}_t$), find the output from each of the ($\mathbf{x}_t$) sectors that are necessary to

[4] In the input-output literature, the terms 'input-output coefficient' and 'direct input coefficient' are used interchangeably.

meet these forecasted final demands. Under the assumption that $(\mathbf{I} - \mathbf{A}_t)^{-1}$ exists, this question may easily be answered by using the following formula

$$\mathbf{x}_t = (\mathbf{I} - \mathbf{A}_t)^{-1}\mathbf{f}_t = \mathbf{L}_t\mathbf{f}_t \tag{9}$$

where matrix $\mathbf{L}_t = (\mathbf{I} - \mathbf{A}_t)^{-1} = \left[l_{ij}^t, i, j = 1,...,n\right]$ is called the 'Leontief inverse.' Formula (9) explains why the model under consideration is called 'demand-driven' – this follows from the fact that the interindustry relationships in a given economy are analyzed from a demand-driven perspective, as $\mathbf{f}_t$ is exogenous and $\mathbf{x}_t$ is endogenous in (9). In this case, the Leontief inverse relates the sectoral gross outputs to the amount of the final product (final demand) – that is, to a unit of the product that leaves the interindustry system at the end of the process (Panek, 2003; Miller and Blair, 2009). In order to shed more light on the interpretation of the elements of the Leontief inverse, let $\bar{\mathbf{f}}_t = \left[\bar{f}_s^t, s = 1,...,n\right]$ correspond to a unit of final demand in sector j during period t; i.e.,

$$\bar{f}_s^t = \begin{cases} 1, \text{ if } s = j \\ 0, \text{ if } s \neq j \end{cases} \tag{10}$$

Model (9) implies that the vector of production that is required to satisfy the demand $\bar{\mathbf{f}}_t$ (i.e., $\bar{\mathbf{x}}_t = \mathbf{L}_t\bar{\mathbf{f}}_t = \left[\bar{x}_s^t, s = 1,...,n\right]$) is equal to the j-th column in matrix $\mathbf{L}_t$. Therefore, l_{ij}^t represents the production of good i; i.e., $\bar{x}_i^t$, which is directly and indirectly needed for each unit of the final demand of good j (Lach, 2020).

Using Formula (9), only the output multipliers can be directly determined; however, the values of these multipliers can serve as a starting point for the calculation of the multipliers that describe the impact of a change in final demand on many types of clearly interpretable economic and non-economic indices. For this purpose, one uses the so-called 'generalized demand-driven Leontief model' given by the following formula

$$\mathbf{e}_t = \hat{\boldsymbol{\pi}}_t\mathbf{L}_t\mathbf{f}_t \tag{11}$$

where the following occur:
$\mathbf{e}_t = \left[e_i^t, i = 1,...,n\right]$ stands for the vector of factor production/use; i.e., e_i^t stands for sector i's production (or use) of a given type of factor during period t (e.g., the number of people employed, the generated income, etc.);

$\hat{\pi}_t = \left[\pi_i^t, i = 1,...,n\right]$ is a vector of direct sectoral coefficients; i.e., π_i^t denotes sector i's direct coefficient that expresses the ratio of production (or use) of a given type of factor in sector i during period t (e.g., the number of people employed, income, etc.) per unit of output in sector i during period t; technically, $e_i^t = \pi_i^t x_i^t$ for i = 1, ..., n.

What is worth emphasizing is the fact that Model (11) is extremely versatile, as it can be employed to analyze any phenomenon that results from conducting a given economic activity. These phenomena include effects that are of a strictly economic nature (like imports, employment, or labor productivity) as well as phenomena with purely social and ecological dimensions (Przybyliński, 2012; Lach, 2020, 2021). In practical applications, it is commonly assumed that the input matrix defined in (5) as well as the vector of direct coefficients defined in (11) are both stable in the short run[5]. Thus, if one assumes that $\mathbf{A}_{t_0} = \mathbf{A}_{t_1} = \mathbf{A}$, $\pi_{t_0} = \pi_{t_1} = \pi$ for initial period t_0 and final period t_1 the linearity of Model (11) implies the following

$$\Delta\mathbf{e} = \hat{\pi}\mathbf{L}\Delta\mathbf{f} \tag{12}$$

where

$\Delta\mathbf{e} = \mathbf{e}_{t_1} - \mathbf{e}_{t_0} = [\Delta e_i, i = 1,\ldots,n]$,

$\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$,

$\Delta\mathbf{f} = \mathbf{f}_{t_1} - \mathbf{f}_{t_0}$.

Model (12) allows one to assess the impact of a change in final demand between t_0 and t_1 (i.e., $\Delta\mathbf{f}$) on the sectoral distribution of the production (or use) of a given type of factor (i.e., $\Delta\mathbf{e}$); e.g., this allows one to track any sectoral changes in the number of employees due to a specific change in sectoral final consumption.

3. Planning a Hyperloop system in Poland

3.1. Description of possible routes

As previously mentioned, one of the key elements of the ongoing "Potential for the development and implementation of vacuum tube high-speed train technology in Poland in the social, technical, economic and legal context" research project is an examination of various hypothetical Hyperloop routes for connecting the largest cities in Poland with the STH. The main goal of the STH will be to integrate all air, rail, and road transport in Poland. Figure 1 shows a diagram of the planned connections between the STH and four Polish cities; namely, Warsaw, Lodz, Krakow and Katowice.

[5] Cf. Carter (1970); Pan (2006); Gurgul and Lach (2018, 2019a, 2019b); Lach (2020).

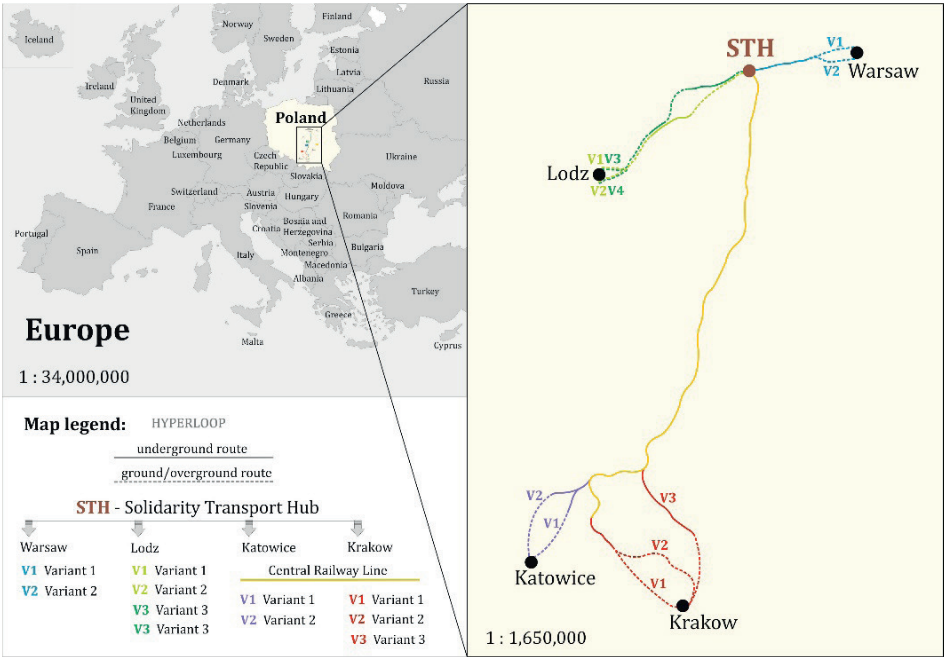

Figure 1. Hypothetical Hyperloop tracks in Poland

source: own elaboration

Different variants (which differ in their construction technology [tunnel and trestle]) are analyzed in reference to each route. Table 1 presents the length of each route (including its variants) while indicating the lengths of the tunnels and trestles. In some cases, the proportion between the lengths of the tunnels and trestles vary significantly.

One of the selection criteria was to ensure that there will be a significant demand for using the proposed routes by passengers. In addition to being able to transport people from the largest Polish cities to the planned STH, the routes that connect Lodz and Warsaw to the STH will also provide more than a 100-km-long direct connection between these two largest agglomerations in Poland. Finally, much longer hypothetical Hyperloop routes were also examined in order to conduct a complete analysis of the possibilities of constructing a Hyperloop system in Poland; i.e., the possibility of constructing a Hyperloop system that connects the STH with slightly smaller cities and agglomerations such as Krakow and Katowice was additionally discussed. This could function as a general pre-feasibility study.

Table 1

Examined variants of Hyperloop lines in Poland

Connection	Variant	Lengths of trestles [km]	Lengths of tunnels [km]	Total lengths of routes [km]
STH-Warsaw	1	14.55	21.36	35.91
	2	14.55	21.10	35.65
STH-Lodz	1	24.77	58.43	83.20
	2	24.77	65.26	90.03
	3	49.31	37.88	87.19
	4	49.31	44.71	94.02
STH-Krakow	1	242.01	47.10	289.12
	2	242.01	55.43	297.44
	3	220.49	34.37	254.86
STH-Katowice	1	205.40	30.99	236.39
	2	223.98	30.99	254.97

Environmental measures were also included in the process of route-planning. In particular, efforts were made to avoid forests, rivers, and large concentrations of people as much as possible. In the surroundings of each city, it was decided to run routes only in tunnels under the surface of the earth. An important assumption was to avoid interfering with the surroundings while at the same time optimizing the routes so that none of the curvatures would result in lowering the Hyperloop's speed limits.

3.2. Cost analysis

In this study, our analysis of the impact of Hyperloop construction on the national economy focuses on examining the costs of the route itself without the infrastructure or capsules[6]. Since the planned Hyperloop routes are partly designed to run on trestles and partly through tunnels, the total construction cost is determined by the costs of the construction of these two particular transport

[6] According to our calculations, the cost of the Hyperloop capsules is only about 3–5% of the total cost of the construction of the Hyperloop routes and, thus, was not taken into account in this analysis.

structures. Table 2 provides information on the construction cost of 10 km of trestles and tunnels, along with information on the share of imports in these costs[7].

Table 2

Average construction costs of 10 km of Hyperloop trestle and tunnel infrastructure in Poland

Type of Hyperloop construction	Total cost (at basic prices) [€]	Share of goods and imported services in total cost [%]	Change in final demand (excluding imported goods for final consumption) [€]
Trestle	695,118,658	16.20	582,509,436
Tunnel	689,565,846	29.06	489,178,011

As mentioned in Section 1, it is of particular importance from the point of view of the analysis carried out in this study that the costs that are reported in Table 2 are broken down into different sections of the Polish Classification of Activities and that the share of the planned imports is also estimated. Table 3 presents the respective details.

Table 3

Sectoral distribution of average costs of building Hyperloop trestles and tunnels in Poland with breakdown of domestic and imported goods[8]

Sector (according to Polish Classification of Activities 2008)	Trestle construction cost		Tunnel construction cost	
	Share of domestic goods [%]	Share of imported goods [%]	Share of domestic goods [%]	Share of imported goods [%]
Crude petroleum and natural gas; metal ores; other mining and quarrying products	1.07	0.00	24.77	0.00

[7] Data on the change in final demand (Tabs 1 and 2) as well as the sectoral distribution of the change in final demand (not including final imported goods) on all of the Hyperloop routes analyzed in this study have been provided by the Polish YLE Engineers design office (http://www.yle.com.pl/).

[8] The distribution of the change in final demand includes those sections for which the change was more than 0.1%. There were 12 such sections out of the 77 sectors listed in Polish Classification of Goods and Services 2008 (https://stat.gov.pl/en/metainformations/classifications/#Polish%20Classification%20of%20Activities%20(PKD)).

Table 3 cont.

Sector (according to Polish Classification of Activities 2008)	Trestle construction cost		Tunnel construction cost	
	Share of domestic goods [%]	Share of imported goods [%]	Share of domestic goods [%]	Share of imported goods [%]
Chemicals and chemical products	0.24	0.00	0.53	2.13
Basic metals	0.56	15.48	0.00	0.00
Machinery and equipment n.e.c.	0.77	0.59	0.23	1.82
Electricity, gas, steam, and air conditioning	0.22	0.00	0.25	0.00
Construction and construction work	77.10	0.00	42.17	24.87
Land and pipeline transport services	1.29	0.00	1.18	0.00
Accommodation services	0.22	0.00	0.21	0.00
Telecommunication services	1.51	0.00	0.75	0.00
Legal and accounting services	0.22	0.00	0.21	0.00
Architectural and engineering services; technical testing and analysis services	0.31	0.00	0.31	0.00
Scientific research and development services	0.30	0.13	0.34	0.22
Total	83.80	16.20	70.96	29.04

When analyzing the data in Table 3, one should pay attention to the fact that imports account for a fairly significant share of the overall construction costs of both Hyperloop transport structures. For the trestles, the costs of the imported goods and services represents more than 16% of the total cost. In the case of trestles, the high value of imports is likely due to the need to use steel in their construction. In Poland, the steel industry has all but disappeared over the last couple of years. Steel is mainly imported from Ukraine, Luxembourg, and the Czech Republic. This does not mean that one cannot produce steel in Poland, but the decisions to import steel are mainly driven by purely economic aspects (as imported steel is much cheaper).

In the case of tunnel construction, the share of imported goods and services is almost 13 percentage points higher than for trestles. This value is mainly due to the need to use suitable machines. Tunnel-building machines (TBM) play an important role in the construction of tunnels (recall the significant share of imported goods in the case of the *Machinery and equipment* sector in Table 3), which are rather technologically advanced and are produced only by companies in a few countries around the world (including China, Turkey, South Korea, Germany, Italy, Australia, and Japan). The prices of these machines are very high because they are based on highly specialized and unique technology.

Tunneling is not only about specialized machines but also about the logistics of operating such machines and equipment; hence, one may note the high value of imports in the *Construction and construction work* sector. Thus, building a Hyperloop system requires the labor input of specialized staff to operate the machines that are used for tunneling.

In the process of constructing Hyperloop tunnels, so-called construction chemicals (the *Chemicals and chemical products* sector) play a major role, as they are a key element regarding the use of sealant. The high value of imports in the case of the *Chemicals and chemical products* sector is due to the fact that the majority of chemical companies in Poland are rather engaged in importing and selling construction chemicals rather than producing them. This is mainly because of the fact that meeting the very high quality standards of producing building chemicals is difficult and costly.

Another important requirement in the process of constructing tunnels is designing and providing development services; hence, the *Scientific research and development services* sector was also included in Table 3. In this respect, Poland has very limited experience with individual projects. This limited experience is due to the simple fact that only few high-tech projects have been implemented to date in Poland. It is worth noting, however, that the central authorities' plans include the need for initiating a number of further tasks of this type, which is likely to result in an increase in the national competencies in this area.

4. Empirical results

In order to simulate the reaction of the national economy to the change in total final demand that is triggered by a particular investment, final demand for imported products should be excluded from the overall cost of the investment (Przybyliński, 2012). Similarly, constructing an input matrix in such a case implies the need for using an interindustry flow table with imports excluded; that is, using an IO table that only describes the flows of domestic goods.

Taking both of these facts into account, the following statistics were used in further parts of this study:

- **A** – domestic input matrix in Poland (i.e., with imports excluded) covering 76 sectors[9] of the economy according to Polish Classification of Goods and Services 2008 (the most recent IO table is based on 2015 data and was published in CSO [2019]);
- $\Delta \mathbf{f}$ – vector of change in final demand due to the particular transport investment (e.g., building a Hyperloop system) covering only domestic products (the initial value is the vector of final demand published in the input-output table for domestic production in Poland in CSO [2019]);
- $\boldsymbol{\pi}$ – vector of direct coefficients defined in two ways:
  - number of people employed in sectors of Polish economy (data for 2015 taken from CSO [2016]) per unit of output (data retrieved from input-output table for domestic production in 2015 [CSO, 2019]),
  - vector of sectoral value added per unit of output (data retrieved from input-output table for domestic production in 2015 [CSO, 2019]).

Table 4 shows the established sectoral distribution of the change in final demand in the Polish economy (without imported final goods and services) implied by the construction of Hyperloop trestles and tunnels. From a formal point of view, this table allows one to obtain vector $\Delta \mathbf{f}$ in Model (12)[10] and then determine the multiplier effects for the three examined policy goal variables.

Table 4

Sectoral distribution of change in final demand
(without imported final goods and services)
caused by construction of Hyperloop trestles and tunnels in Poland

Sector (according to Polish Classification of Activities 2008)	Trestles [%]	Tunnels [%]
Crude petroleum and natural gas; metal ores; other mining and quarrying products	1.28	34.92
Chemicals and chemical products	0.29	0.75

[9] In general, the national IO table published by the CSO (2019) is of a size of 77 × 77. However, there were no inflows and no outflows in the case of the *Private Households with Employed People* sector. Thus, we excluded this sector from the empirical analysis and focused on an IO table of a size of 76 × 76.

[10] To obtain vector $\Delta \mathbf{f}$ in Model (12) for a particular Hyperloop track, one should split the total cost of the construction (Tab. 2) into trestle- and tunnel-related components and then multiply each of these components by the respective vector of sectoral distribution of the change in final demand (without imported final goods and services) given in Table 4.

Table 4 cont.

Basic metals	0.67	0.00
Machinery and equipment n.e.c.	0.91	0.33
Electricity, gas, steam, and air conditioning	0.26	0.35
Construction and construction work	92.00	59.45
Land and pipeline transport services	1.54	1.66
Accommodation services	0.26	0.30
Telecommunication services	1.80	1.05
Legal and accounting services	0.26	0.30
Architectural and engineering services; technical testing and analysis services	0.37	0.44
Scientific research and development services	0.36	0.45

Table 5 presents the aggregate multiplier effects (calculated by using the methodology described in Section 1) implied by the construction of 10 kilometers of trestles and 10 kilometers of tunnels regarding the Hyperloop technology in Poland[11].

Table 5

Aggregate change in output, value added, and number of employees in Polish economy implied by construction of 10-km-long Hyperloop trestles and tunnels in Poland (source: own elaboration)

Type of Hyperloop construction	Output [mln €]	Number of employees [no. of people]	Value added [mln €]
Trestle	1,114.345	13,481	449.931
Tunnel	874.693	10,666	372.468

[11] Since IO analysis remains one of the few analytical tools that does not explicitly present error bounds in data tables (Lach, 2020), a sensitivity analysis of the empirical results that were obtained in this study was additionally carried out. Simply put – for each examined IO model, the validation procedure consisted of independently drawing 5,000 input matrices from a uniform distribution that was centered on the actual input matrix (i.e., based on the data published by the CSO) with symmetrical ±5% bounds on any possible coefficient change and then constructing the IO models on the basis of the resampled input matrices. Since the empirical confidence intervals for all of the multiplier effects turned out to be extremely narrow, we have not reported the results of the sensitivity analysis in detail. These supplemental results are available from the authors upon request.

As can be seen in Table 5, the aggregate multiplier effects implied in the Polish economy by the construction of 10 km of the two selected types of transport structures are higher in the case of the construction of a Hyperloop trestle than that of a tunnel. This is the case for the aggregate multiplier effects calculated for both the value added and output as well as employment. There is a discernible difference between the output and employment multipliers, however. For example, the construction of 10 kilometers of Hyperloop trestles will generate nearly 13,500 additional jobs; in the case of tunnel construction, this employment effect will be about 10,700 new jobs. The analogous difference between the global production multipliers is also quite significant (nearly €350 million). On the other hand, the (important) indicator of total value added is approximately €70 million higher for the construction of a 10-km-long Hyperloop trestle. This effect is largely due to the much higher share of imported goods in the total cost of building a Hyperloop tunnel in Poland as compared to the construction of a Hyperloop trestle.

Table 6 presents the sectoral distribution of output, value added, and number of employees in the Polish economy that are likely to be generated by the construction of 10 km of Hyperloop trestles and tunnels in Poland.

Table 6

Sectoral distribution of output, value added, and number of employees in Polish economy implied by construction of 10-km-long Hyperloop trestles and tunnels

Sector (according to Polish Classification of Activities 2008)	Trestle			Tunnel		
	Output [mln €]	Number of employees [no. of people]	Value added [mln €]	Output [mln €]	Number of employees [no. of people]	Value added [mln €]
Agriculture and hunting products	1.165	118	0.396	0.945	96	0.321
Forest management products	2.222	43	1.029	1.523	30	0.705
Fish and other fishery products	0.010	0	0.005	0.007	0	0.003
Hard and brown coal	2.586	54	1.552	2.099	44	1.260
Crude oil and natural gas, metal ores, other mining products	17.923	208	8.592	195.336	2265	93.639
Groceries	2.106	20	0.469	1.527	15	0.340

Table 6 cont.

Drinks	0.582	3	0.169	0.440	2	0.128
Tobacco products	0.010	0	0.006	0.008	0	0.005
Textile goods	0.290	6	0.074	0.217	5	0.056
Clothing	0.263	9	0.137	0.208	7	0.108
Leather and leather goods	0.067	2	0.022	0.066	1	0.022
Wood and wood products	13.613	206	4.142	7.760	118	2.361
Paper and paper products	3.179	22	0.916	2.442	17	0.703
Printing and reproduction services	1.078	19	0.357	0.835	15	0.276
Coke, refined petroleum products	12.963	14	1.472	10.944	12	1.243
Chemicals, chemical products	8.291	44	2.447	8.419	44	2.485
Medicines and pharmaceutical products	0.038	0	0.011	0.036	0	0.010
Rubber and plastic products	27.082	312	7.505	16.164	186	4.479
Products from other non-metallic raw materials	41.850	498	14.638	23.395	278	8.183
Metals	12.135	56	2.457	4.979	23	1.008
Finished metal products	33.404	491	12.503	19.982	294	7.479
Computers, electronic, and optical products	1.021	8	0.168	0.665	5	0.109
Electrical and non- electrical appliances, household appliances	3.561	29	1.021	2.154	17	0.618
Machines and devices not elsewhere classified	7.424	90	2.698	3.594	44	1.306
Motor vehicles, trailers, and semi-trailers	2.691	18	0.440	2.560	17	0.419
Other transport equipment	0.480	4	0.168	0.568	5	0.198
Furniture	1.278	24	0.421	0.894	17	0.294
Other products	0.243	5	0.098	0.185	3	0.075

Table 6 cont.

Sector (according to Polish Classification of Activities 2008)	Trestle			Tunnel		
	Output [mln €]	Number of employees [no. of people]	Value added [mln €]	Output [mln €]	Number of employees [no. of people]	Value added [mln €]
Repair, maintenance, and installation services of machines and devices	11.508	139	5.279	11.520	139	5.284
Electricity, gas, steam, and hot water	15.056	75	6.594	15.231	76	6.670
Water; water treatment, and supply services	1.141	26	0.807	1.003	23	0.710
Waste-related services; recovery of raw materials	2.601	23	0.976	1.558	14	0.584
Sewage services; sediments; remediation services	1.492	41	0.960	1.691	47	1.088
Building objects and construction work	691.434	7523	269.305	377.276	4105	146.944
Sales of motor vehicles; vehicle repair	2.990	63	1.845	2.840	60	1.752
Wholesale trade	33.887	654	17.316	21.095	407	10.780
Retail trade	12.848	367	8.874	9.600	275	6.631
Land and pipeline transport	36.469	554	14.443	35.077	533	13.891
Water and air transport	0.575	1	0.184	0.698	1	0.224
Storage; postal and courier services	9.008	65	4.241	10.052	72	4.733
Accommodation services	2.875	66	1.446	2.530	58	1.273
Food-related services	1.465	38	0.565	1.054	27	0.407
Services related to publishing activities	0.639	9	0.283	0.664	9	0.295
Services related to production of films, television programs, and recordings	0.093	1	0.035	0.075	1	0.028

Table 6 cont.

Related services with broadcasting	0.404	3	0.201	0.369	3	0.184
Telecommunication services	13.788	74	6.106	7.638	41	3.382
Computer software and consultancy services	4.034	64	2.388	2.990	47	1.770
Information services	1.186	21	0.577	0.891	16	0.433
Financial services	7.278	117	4.746	6.375	102	4.158
Insurance services	1.590	9	0.518	1.200	7	0.391
Services auxiliary to financial and insurance services	0.629	12	0.254	0.451	9	0.182
Related services with real estate market services	6.334	37	3.360	5.002	29	2.653
Legal and accounting services	6.879	170	4.622	5.948	147	3.997
Management consulting services	5.999	104	3.388	4.580	80	2.587
Architectural and engineering services; technical research and analysis services	10.929	188	6.342	8.421	145	4.887
Research and development services	2.144	26	1.479	2.253	27	1.555
Advertising services; market research and public opinion-polling services	7.708	52	3.372	6.369	43	2.786
Other professional, scientific, and technical services	1.165	21	0.728	1.673	31	1.046
Veterinary services	0.036	1	0.026	0.024	0	0.017
Rent and lease	7.150	29	4.635	6.240	25	4.045
Employment-related services	4.053	243	3.045	2.543	152	1.910
Tourism organizer services	0.090	1	0.016	0.074	0	0.013

Table 6 cont.

Sector (according to Polish Classification of Activities 2008)	Trestle			Tunnel		
	Output [mln €]	Number of employees [no. of people]	Value added [mln €]	Output [mln €]	Number of employees [no. of people]	Value added [mln €]
Detective and security services	2.133	114	1.277	1.989	106	1.191
Services related to maintaining order in premises	0.884	32	0.405	0.755	27	0.346
Office administrative services	3.262	52	1.899	4.141	66	2.411
Public administration services	0.993	36	0.754	1.247	45	0.947
Education services	0.938	51	0.722	0.771	42	0.593
Healthcare services	0.642	19	0.367	0.505	15	0.289
Social assistance services	0.000	0	0.000	0.000	0	0.000
Cultural and entertainment services	0.067	2	0.036	0.049	1	0.026
Libraries, archives, and museums	0.026	3	0.013	0.029	3	0.014
Gaming and betting services	0.000	0	0.000	0.000	0	0.000
Sports, entertainment, and recreation services	0.140	3	0.059	0.095	2	0.040
Member organization services	0.158	17	0.043	0.136	15	0.037
Repair and maintenance services for computers and household goods	1.351	13	0.994	1.327	13	0.976
Other individual services	0.719	23	0.493	0.693	22	0.473

In general, the empirical results that are presented in Table 6 support the claim that there is a discernible difference between the sectoral distributions of the analyzed multiplier effects that are implied by the construction of Hyperloop trestles and tunnels. In the case of the construction of a 10-km-long Hyperloop trestle, the largest sectoral multiplier effects induced in the Polish economy concern the *Building objects and construction work* sector, because this sector accounts for 50% of the overall induced value added and the additional employment falls on this sector. Significant multiplier effects were also achieved (around 3–4%) in the case of the following sectors: *Products from other non-metallic raw materials*, *Land and pipeline transport*, *Wholesale trade*, *Finished metal products*.

In the case of tunnel construction, also the greatest multiplier effects (by far) were achieved in the case of the *Building objects and construction work* sector in the case of constructing a 10-km-long Hyperloop tunnel. This sector accounts for about 40% of the total induced employment and value added. A significant share of the overall induced employment and value added (around 20–25%) was reported in the case of the *Crude oil and natural gas, metal ores, other mining products* sector.

As the costs of building a 10-km Hyperloop trestle and a 10-km Hyperloop tunnel in Poland are very similar, the decision as to whether a particular section of a Hyperloop route should be led by a trestle or a tunnel may be based on the need to support specific sectors of the economy. Although the multiplier effects presented in Table 6 were induced by the construction of 10 kilometers of a Hyperloop trestle and 10 kilometers of a Hyperloop tunnel, they straightforwardly translate into the total size of these effects that would occur after constructing all of the planned Hyperloop routes as well as the variants discussed in this study. Table 7 shows the results of the aggregate multiplier effects that would be induced by the construction of the Hyperloop routes depicted in Figure 1[12].

The aggregate multiplier effects that are presented in Table 7 vary significantly among the proposed Hyperloop routes. This is mainly related to their lengths; however, it is to some extent also related to the type of route (one mainly leading along trestles as opposed to one leading mainly through tunnels). Therefore, it seems reasonable at this stage to individually compare the variants of the Hyperloop routes that connect the STH with a chosen city. In the case of the STH-Warsaw connection, the resulting multiplier effects are very similar for both of the examined variants of the Hyperloop route. In the case of this connection, the number of generated new jobs comes to more than 42,000 regardless of the variant of the route. On the other hand, the value added that results from the construction of these two variants of the Hyperloop route is equal to approximately €1,450 ml. Thus, the multiplier effects do not significantly differentiate the proposed variants of the Hyperloop route in terms of the impact on the economy in the case of this connection. Also, there are no significant differences between the multiplier

[12] To save space, the sectoral distributions of the connection-specific multiplier effects of all of the examined Hyperloop routes are not given in detail. However, these supplemental results are available from the authors upon request.

values that are reported for Route Variants 1 and 2 in Table 7 in the case of the route that connects the STH with Katowice.

Table 7

Aggregate change in output, value added, and number of employees in the Polish economy induced by construction of Hyperloop routes depicted in Figure 1

Connection	Output [mln €]	Number of employees [no. of people]	Value added [mln €]
STH-Warsaw (V1)	3,477.95	42,259	1,444.46
STH-Warsaw (V2)	3,458.48	42,024	1,436.19
STH-Lodz (V1)	7,821.20	95,229	3,271.89
STH-Lodz (V2)	8,422.49	102,534	3,525.39
STH-Lodz (V3)	8,677.05	105,443	3,578.28
STH-Lodz (V4)	9,356.34	113,580	3,863.52
STH-Krakow (V1)	30,511.95	369,458	12,409.63
STH-Krakow (V2)	31,432.06	380,950	12,801.62
STH-Krakow (V3)	27,515.45	333,359	11,179.59
STH-Katowice (V1)	25,530.78	309,488	10,370.09
STH-Katowice (V2)	27,188.37	329,603	11,041.81

The discussed dependencies are slightly different in the cases of STH-Lodz and STH-Krakow connections. For Variant 1 of the STH-Lodz connection, the number of additional employees comes to more than 95,000, and for Variant 4, this effect creates 113,000 new jobs (nearly 19% more). Variants 1 and 4 also differ in terms of the value added, as the induced value added is more than €3,860 million in the case of Variant 4 (which is more than 118% of the corresponding multiplier effect that is reported for Variant 1 of STH-Lodz Hyperloop connection). Therefore, if one assumes that the induced value added is the leading indicator of the impact of Hyperloop construction on the national economy, one should decide to build Variant 4 of the STH-Lodz connection. Analogously, among the variants of Hyperloop routes that connect the STH with Krakow, one can easily identify the variant that has the greatest multiplier effects regardless of the chosen policy goal variable (i.e., output, value added, new jobs). Namely, the construction of Variant 2 of this Hyperloop connection would generate more than 381,000 jobs, while in Variant 1 of this particular connection, the number of generated new jobs is only approximately 333,000 (which is nearly 50,000 fewer new jobs).

5. Conclusions

The purpose of this study was to specify the multiplier effects that are potentially induced in the national economy in reference to the construction of Hyperloop lines in Poland using tunnel and trestle technologies. Our examination focused on the cost of constructing a 10-km-long tunnel as well as a 10-km-long trestle. Due to the lower utilization of imported goods, the impact of trestle construction (value-added and employment) is greater than tunnel construction. The purpose of the multiplier analysis was not only to determine the overall impact of such an investment on the national economy but also to list the sectors of the economy that could be expected to experience the greatest stimulation. According to the conducted analysis, constructing Hyperloop links in Poland would have the greatest stimulating impact on several sectors of the Polish economy, including *Building objects and construction work*, *Crude oil and natural gas, metal ores, other mining products*, *Products from other non-metallic raw materials*, *Finished metal products*, *Land and pipeline transport*, and *Wholesale trade.* Additionally, we compared the impact of the construction of tunnels as well as trestles on the development of a particular industry. Our results indicated that the costs of both technologies are similar; however, the impact of each technology is different on particular industries. We also identified those routes (and their construction technologies) that are the most efficient in terms of multiplier effects.

Our examination corresponds with numerous studies on the socioeconomic impact of transport infrastructure – especially railway infrastructure (some of these are presented in the Introduction section). The results of our study confirm the positive impact of investments in transportation infrastructure. The results of our study induce other questions and highlight other challenges. For example, the construction process will result in an increase in employment; however, we have not examined the long-term impact of Hyperloop infrastructure development on employment. Our analysis focused on the short-term impact of construction investments but the long-term impact of Hyperloop passenger and cargo transportation can be analyzed as well.

This study contributes to the body of literature on transport infrastructure and public investments as well as Hyperloop technology development. Additionally, it contributes to the econometric methodology by employing input-output analysis for forecasting the multiplier effects of constructing a Hyperloop network. This study has practical implications for the decision-making process on Hyperloop network planning and development in the future. In particular, this study delivers indications for decision-makers who will need to decide whether or not to invest in technologies that are necessary for the construction of a Hyperloopnetwork (which would enable an increase in the multiplier effect of the Hyperloop construction on the economy).

When interpreting the obtained empirical results, one cannot forget that the input-output table as well as both vectors of the direct coefficients (one related to the number of employees, and the other expressing the value added per unit of output) were all based on data from 2015. The application of 2015 data in constructing short-run forecasts was caused by the lack of availability of more-recent statistical IO datasets on Poland. In other words, we assumed the short-term stability of the parameters of IO models in this paper, which is a common practice in empirical IO analyses; comp. Carter (1970), Pan (2006), Gurgul and Lach (2018, 2019a, 2019b), Lach (2020), etc.

On the one hand, the linear form of the IO model is a rather far-reaching simplification of reality; on the other hand, it ensures an ease of calculation and clarity of interpretation of the obtained results. These simplifications are mainly caused by equating the average and marginal quantities in the IO model (Przybyliński, 2012). What is most important, the interpretation of input-output multipliers is based on the assumption that there are capacity reserves in the economy under analysis that allow for increasing production accordingly without the need for technological progress (Przybyliński, 2012). This assumption is relatively restrictive, as it assumes that there are no supply constraints in the economy (Cardenete and Sancho, 2012). To some extent, this issue can be avoided by using CGE-class models, which – among the many advantages – allow us to introduce supply constraints in the equations that describe the production processes (Lach, 2020). Due to the need to establish the exact values of a very large number of hyperparameters as well as a relatively high degree of complexity and sensitivity to the choice of the closure (Dietzenbacher et al., 2013), the calibration and correct application of CGE-class models does not seem possible at the current stage of analytical work on assessing the feasibility and efficiency of a Hyperloop system in Poland. In other words, we fully agree with Blanquart and Koning (2017) and Lee et al. (2018), who underlined that the linear IO model still seems to be the most reliable quantitative tool that is available in the context of forecasting the multiplier effects of constructing a Hyperloop infrastructure.

It should also be underlined that the calculated multiplier effects relate to the full period of constructing a Hyperloop system in Poland. As previously mentioned, Model (12) assesses the sectoral effects of the change in final demand for the sectoral distribution of the production/use of a given factor over a whole time period between t_0 and t_1. The way the particular aggregate multiplier effect will be distributed over time during period t_0 to t_1 depends on the actual detailed plan of the investments (including the details of a financial schedule). Our analysis does not take inflation into account, which can change over time and impact our calculations.

Our analysis focused on several aspects that are associated with developing a Hyperloop infrastructure in Poland. However, some questions remain to be answered. One of these relates to a comparison of investments and the impact of a Hyperloop on other transportation technologies (e.g., highways and traditional/high-speed railways) as an alternative for the routes examined in our study. Such a comparison would be an important argument in the decision-making process. Our results do not reflect the potential profits that may be sourced in licensing as well as the sale of construction services abroad. As an additional long-term source of income, spin-off technologies are not included in our calculations (even though many new solutions may appear along with the development of the Hyperloop technology); some of these technologies may be bases for new products and markets.

Finally, it should be highlighted that the presented project has not yet been implemented (as is true with any other Hyperloop network projects around the world; there are only some pieces of testing the infrastructure that have been constructed). Moreover, it has not been decided whether the examined infrastructure within this study will be implemented in the future; however, this analysis was triggered by a governmental research project that was focused on Hyperloop technology, which suggests that such an investment is under consideration. Thus, we can posit that some obstacles and negative consequences may appear. Many of these will likely be connected with the technology; for example, there have been some safety issues that have not yet been addressed. In the area of socio-economic determinants, we need to consider the impact of long-term global economic development and economic prosperity; these can affect demand, costs, resources, and capital availability. In particular, a potential economic crisis (which is a part of any economic reality) could affect public investment; the current COVID-19 pandemic is a good example. However, we still do not know the scale and scope of its impact – especially in the long term. In this context, the EU recovery plan (which is intended to promote environment-friendly solutions) may be a favorable factor for the development of technologies such as Hyperloop (for example, as an alternative to short- and middle-haul air transportation routes). Consequently, the presented analysis may require modifications in the future depending on the numerous conditions that can affect the implementation of Hyperloop as a mode of transportation.

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References

[1] Agénor, P.R. and Moreno-Dodson, B. (2006) 'Public Infrastructure and Growth: New Channels and Policy Implications', *Policy Research Working Paper*, 4064. World Bank, Washington, DC.

[2] Alam, K.M., Li, X., Baig, S., Ghanem, O. and Hanif, S. (2020) 'Causality between transportation infrastructure and economic development in Pakistan: An ARDL analysis', *Research in Transportation Economics*, vol. 88, 100974.

[3] Baldwin, J.R. and Dixon, J. (2008) Infrastructure Capital: What Is It? Where Is It? How Much of It Is There?, Ottawa: Minister of Industry.

[4] Białas, M., Duda, J. and Surowiec, A. (2020) 'Economic factors of vacuum rail's competitiveness in Poland compared to alternative solutions', *New Trends in Production Engineering*, vol. 3, pp. 439–449.

[5] Blanquart, C. and Koning, M. (2017) 'The local economic impacts of high-speed railways: theories and facts', *European Transport Research Review*, vol. 9, Article 12.

[6] Bristow, A.L. and Nellthorp, J. (2000) 'Transport project appraisal in the European Union', *Transport Policy*, vol. 7(1), pp. 51–60.

[7] Cardenete, M.A. and Sancho, F. (2012) 'The role of supply constraints in multiplier analysis', *Economic System Research*, 24(1), pp. 21–34.

[8] Carter, A. (1970) Structural change in the American economy, Cambridge: Harvard University Press.

[9] Cigu, E., Agheorghiesei, D.T., Gavriluță (Vatamanu), A.F. and Toader, E. (2019) 'Transport Infrastructure Development, Public Performance and Long-Run Economic Growth: A Case Study for the EU-28 Countries', *Sustainability*, vol. 11, Article 67.

[10] Chang, Y., Yang, Y. and Dong, S. (2018) 'Comprehensive Sustainability Evaluation of High-Speed Railway (HSR) Construction Projects Based on Unascertained Measure and Analytic Hierarchy Process', *Sustainability*, vol. 10, Article 408.

[11] Chen, Z. (2019) 'Measuring the regional economic impacts of high-speed rail using a dynamic SCGE model: the case of China', *European Planning Studies*, vol. 27(3), pp. 483–512.

[12] CSO (2016) *Employment in national economy in 2015*, Warsaw, Central Statistical Office of Poland.

[13] CSO (2019) *Input-output table at basic prices in 2015*, Warsaw, Central Statistical Office of Poland.

[14] Diao, M. (2018) 'Does growth follow the rail? The potential impact of high-speed rail on the economic geography of China', *Transportation Research Part A: Policy and Practice*, vol. 113, pp. 279–290.

[15] Dietzenbacher, E., Lenzen, M., Los, B., Guan, D., Lahr, M.L., Sancho, F., Suh, S. and Yang, C. (2013) 'Input-output analysis: The next 25 years', *Economic Systems Research*, vol. 25(4), pp. 369–389.

[16] Duchin, F. and Steenge, A.E. (2007) 'Mathematical models in input-output economics', Working Papers in Economics 0703, New York, Rensselaer Polytechnic Institute.

[17] Duda, J., Kusa, R., Rumin, R., Suder, M. and Feliks, J. (2021) 'Identifying the determinants of vacuum tube high-speed train development with technology roadmapping – a study from Poland', *European Planning Studies*, vol. 30(2), pp. 405–424.

[18] Gherghina, Ş.C., Onofrei, M., Vintilă, G. and Armeanu, D.Ş. (2018) 'Empirical Evidence from EU-28 Countries on Resilient Transport Infrastructure Systems and Sustainable Economic Growth', *Sustainability*, vol. 10, Article 2900.

[19] Gurgul, H. and Lach, Ł. (2018) 'On using dynamic IO models with layers of techniques to measure value added in global value chains', *Structural Change and Economic Dynamics*, vol. 47, pp. 155–170.

[20] Gurgul, H. and Lach, Ł. (2019a) 'On approximating the accelerator part in dynamic input-output models', *Central European Journal of Operations Research*, vol. 27(1), pp. 219–239.

[21] Gurgul, H. and Lach, Ł. (2019b) 'Tracing VARDI coefficients: A proposal', *Economic Systems Research*, vol. 31, pp. 324–344.

[22] Holmgren, J. and Merkel, A. (2017) 'Much ado about nothing? – A meta-analysis of the relationship between infrastructure and economic growth', *Research in Transportation Economics*, vol. 63, pp. 13–26.

[23] Hromádka, V., Korytárová, J., Vítková, E., Seelmann, H. and Funk, T. (2020) 'New Aspects of Socioeconomic Assessment of the Railway Infrastructure Project Life Cycle', *Applied Sciences*, vol. 10, Article 7355.

[24] Ke, X., Lin, J.Y., Fu, C. and Wang, Y. (2020) 'Transport Infrastructure Development and Economic Growth in China: Recent Evidence from Dynamic Panel System-GMM Analysis', *Sustainability*, vol. 12, Article 5618.

[25] Khan, H., Khan, U., Jiang, L.J. and Khan, M.A. (2020) Impact of infrastructure on economic growth in South Asia: Evidence from pooled mean group estimation. *The Electricity Journal*, vol. 33(5), Article 106735.
[26] KPMG (2016) Pre-feasibility study Stockholm-Helsinki using Hyperloop-One technology. Short summary, [Online] Available: https://assets.kpmg [20 Aug 2021].
[27] Lach, Ł. (2020) Tracing key sectors and important input-output coefficients: Methods and applications, Warszawa: C.H. Beck.
[28] Lach, Ł. (2021) 'On the plausibility of using linear programming to trace important input-output coefficients in the framework of tolerable limits', *Economic Systems Research*, vol. 33, pp. 417–426.
[29] Lee, C., Ma, J. and Oh, K.K. (2018) 'Economic Impact Analysis on Regional Industries by High-Speed Rail Investments: Application of an Input-Output Model', *Transportation Research Record*, vol. 2672, pp. 247–259.
[30] Lee, M.-K. and Yoo, S.-H. (2016) 'The role of transportation sectors in the Korean national economy: An input-output analysis', *Transportation Research Part A: Policy and Practice*, vol. 93, pp. 13–22.
[31] Li, F., Su, Y., Xie, J., Zhu, W. and Wang, Y. (2020) 'The Impact of High-Speed Rail Opening on City Economics along the Silk Road Economic Belt', *Sustainability*, vol. 12, Article 3176.
[32] Meersman, H. and Nazemzadeh, M. (2017) 'The contribution of transport infrastructure to economic activity: The case of Belgium', *Case Studies on Transport Policy*, vol. 5(2), pp. 316–324.
[33] Miller, R.E. and Blair, P.D. (2009) Input-Output Analysis, New York: Cambridge University Press.
[34] Mentolio, D. and Solé-Ollé, A. (2009) 'Road investment and regional productivity growth: the effects of vehicle intensity and congestion', Papers in Regional Science, vol. 88, pp. 99–118.
[35] Moyano, A., Rivas, A. and Coronado, J.M. (2019) 'Business and tourism high-speed rail same-day trips: factors influencing the efficiency of high-speed rail links for Spanish cities', *European Planning Studies*, vol. 27(3), pp. 533–554.
[36] Muvawala, J., Sebukeera, H. and Ssebulime, K. (2020) 'Socio-economic impacts of transport infrastructure investment in Uganda: Insight from front-loading expenditure on Uganda's urban roads and highways', *Research in Transportation Economics*, vol. 88, Article 100971.
[37] Myszczyszyn, J. and Mickiewicz, B. (2020) 'Analysis of the Interdependence between the Economic Growth and the Development of the Railway Sector', *European Research Studies Journal*, vol. 23(1), pp. 491–506.
[38] Naranjo Gómez, J.M. (2016) 'Impacts on the Social Cohesion of Mainland Spain's Future Motorway and High-Speed Rail Networks', *Sustainability*, vol. 8, Article 624.

[39] Quium Abdul, A.S.M. (2019) Transport Corridors for Wider Socio-Economic Development, *Sustainability*, 11, Article 5248.
[40] Pan, H. (2006) 'Dynamic and endogenous change of input-output structure with specific layers of technology', *Structural Change and Economic Dynamics*, vol. 17, pp. 200–223.
[41] Panek, E. (2003) Ekonomia matematyczna (Mathematical economics), Poznań: Wydawnictwo Akademii Ekonomicznej.
[42] Przybyliński, M. (2012) Metody i tablice przepływów międzygałęziowych w analizach handlu zagranicznego Polski (Input-output methods and tables in analyses of Poland's foreign trade), Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
[43] Schodl, R., Eitler, S., Ennser, B., Breinbauer, A., Hu, B., Markvica, K., Prandtstetter, M., Zajicek, J., Berger, T., Pfoser, S., Berkowitsch, C. and Hauger, G. (2018) 'Innovative means of cargo transport: A scalable method for estimating regional impacts', *Transportation Research Procedia*, vol. 30, pp. 342–349.
[44] Stryhunivska, O., Gdowska, K. and Rumin, R. (2020) 'A concept of integration of a vactrain underground station with the Solidarity Transport Hub Poland', *Energies*, vol. 13(21), Article 5737.
[45] Sun, J., Li, Z., Lei, J., Teng, D. and Li, S. (2018) 'Study on the Relationship between Land Transport and Economic Growth in Xinjiang', *Sustainability*, vol. 10, Article 135.
[46] Tomaszewicz, Ł. (1983) Zintegrowane modele gospodarki narodowej (Integrated models of national economy), Warszawa: Państwowe Wydawnictwo Ekonomiczne.
[47] Wang, Y., Liu, X. and Wang, F. (2018) 'Economic Impact of the High-Speed Railway on Housing Prices in China', *Sustainability*, vol. 10, Article 4799.
[48] Yin, P., Pagliara, F. and Wilson, A. (2019) 'How Does High-Speed Rail Affect Tourism? A Case Study of the Capital Region of China', *Sustainability*, vol. 11, Article 472.
[49] Yu, X., Lang, M., Gao, Y., Wang, K., Su, C.-H., Tsai, S.-B., Huo, M., Yu, X. and Li, S. (2018) 'An Empirical Study on the Design of China High-Speed Rail Express Train Operation Plan – From a Sustainable Transport Perspective', *Sustainability*, vol. 10, Article 2478.
[50] Zou, W., Zhang, F., Zhuang, Z. and Song, H. (2008) 'Transport Infrastructure, Growth and Poverty Alleviation: Empirical Analysis of China', *Annals of Economics and Finance*, vol. 9(2), pp. 345–371.

Summary

The aim of this paper is to specify the multiplier effects that are induced in the national economy in reference to the construction of Hyperloop lines in Poland using tunnel and trestle technology. In particular, we calculate the added value and employment growth for several industries that will contribute to the construction process. We use an input-output analysis that enables us to take the detailed structure of interindustry linkages in Poland into account. According to our results, constructing a Hyperloop infrastructure in Poland would have the greatest stimulating impact on several sectors of the Polish economy, including crude oil and natural gas, metal ores, other mining products, building objects and construction work, products from other non-metallic raw materials, finished metal products, land and pipeline transport, and wholesale trade. However, this impact will be affected by the choice of construction technology (tunnel versus trestle). In addition, our calculations relate to particular routes of the potential Hyperloop network. This study contributes to the body of literature on transport infrastructures and public investments as well as Hyperloop technology development. Additionally, it contributes to the econometric methodology by employing an input-output analysis for forecasting the multiplier effects of constructing a Hyperloop system. This study has practical implications for the decision-making process on Hyperloop network development in the future.

JEL codes: M21, O11, O14, O33, O41, O47, R42

Keywords: *vacuum tube high-speed train; Hyperloop; input-output (IO) analysis; economic development; technology development; interdisciplinary studies*

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In general, the authors should use the Harvard style of referencing. References to literature within the text should be given in the form: the name of the author(s) and the year of publication (in parentheses), e.g. "Smith (1990) underlines…", "As shown in Smith (1990)…". In case of more than two authors of the cited publication the "et al." shortcut should be used.

Lists of references should be written in alphabetical-chronological order, numbered and follow the rules:

- JOURNAL ARTICLE

Muller, V. (1994) 'Trapped in the body: Transsexualism, the law, sexual identity', *The Australian Feminist Law Journal*, vol. 3, August, pp. 103–107.

- BOOKS

Book with one author

Adair, J. (1988) Effective time management: How to save time and spend it wisely, London: Pan Books.

Book with two authors

McCarthy, P. and Hatcher, C. (1996) Speaking persuasively: Making the most of your presentations, Sydney: Allen and Unwin.

Book with three or more authors

Fisher, R., Ury, W. and Patton, B. (1991) Getting to yes: Negotiating an agreement without giving in, 2nd edition, London: Century Business.

Book – second or later edition

Barnes, R. (1995) Successful study for degrees, 2nd edition, London: Routledge.

Book by same author in the same year

Napier, A. (1993a) Fatal storm, Sydney: Allen and Unwin.
Napier, A. (1993b) Survival at sea, Sydney: Allen and Unwin.

Book with an editor

Danaher, P. (ed.) (1998) Beyond the ferris wheel, Rockhampton: CQU Press.

A chapter in a book

Byrne, J. (1995) 'Disabilities in tertiary education', in Rowan, L. and McNamee, J. (ed.) Voices of a Margin, Rockhampton: CQU Press.

- WORLD WIDE WEB PAGE

Young, C. (2001) English Heritage position statement on the Valletta Convention, [Online], Available: http://www.archaeol.freeuk.com/EHPostionStatement.htm [24 Aug 2001].

- CONFERENCE PAPERS

Hart, G., Albrecht, M., Bull, R. and Marshall, L. (1992) 'Peer consultation: A professional development opportunity for nurses employed in rural settings', Infront Outback – Conference Proceedings, Australian Rural Health Conference, Toowoomba, pp. 143–148.

- NEWSPAPER ARTICLES

Cumming, F. (1999) 'Tax-free savings push', Sunday Mail, 4 April, p. 1.

All the items cited in the main text, and no other items, must be placed in the list of references.

Authors should include 2–3 JEL codes with manuscript during submission. For more details on the JEL classification system CLICK HERE.

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Double blind peer review procedure

1. In order to assess a quality of submitted publication the Editorial Board consults at least two outside referees (not affiliated to any of the authors' institutions) which are recognized experts in the specific field.

2. At least one of the referees must represent a foreign institution (i.e. an institution located in other country than the home institution of each author).

3. The journal uses double blind peer review policy, i.e. neither the author nor the referee knows the identity of the other. In addition, each referee signs a declaration of no conflict of interests, whereby the conflict of interest is defined as a direct personal relationship (kinship to the second degree, legal relationships, marriage) or a professional scientific cooperation between the referee and the author which took place at least once in the past two years preceding the year of accepting the invitation to review.

4. Only written referee reports are considered (journal does not accept face-to-face or phone-call- based reports). Each report should clearly express the referee's final recommendation (i.e. whether the article should be accepted for publication, revised or rejected). The referees are kindly requested to fill the review form which can be found in "For reviewers" section. In general, the referees are asked to:

– assess:

- the scientific importance of the submission's topic,
- the quality of research;

– verity whether:

  - the Abstract is concise and informative,
  - the facts and interpretations are satisfactorily separated in the text,
  - the interpretations and conclusions follow from the data,
  - the length and structure of the paper is appropriate,
  - the paper can be shortened without loss of quality,

- all the tables and figures are necessary,
- the diagrams and photographs are of good quality,
- there are all essential figures that should be prepared,
- all the references are exact,
- the manuscript requires proof reading by native speaker,
- there is sufficient attention given to previous research.

5. The names of the referees of particular articles are classified.

6. Once a year the journal publishes the complete list of referees.