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DOMESTIC AND FOREIGN TRANSMISSION OF THE GLOBAL FINANCIAL CRISIS IN THE REAL ECONOMY. THE POLISH SITUATION

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Abstract. This paper studies the contagion process of the 2008 Global Financial Crisis through several important Polish economic sectors: chemical, construction, food, IT, media, oil & gas and telecommunication. The results show a significant difference between the response of these sectors to the crisis. Chemical, construction, media and oil and gas were affected, in different degrees, by a domestic financial contagion. The food industry was influenced in a negligible degree by contagion, while the IT and telecommunication sectors showed a decrease of their co-movements with the financial sector, both foreign and domestic.

1. Introduction

Financial contagion has been an important subject in financial literature and, presumably, it will remain crucial, especially given the current situation of the COVID-19 pandemic and its human and economic implications. One of the main purposes in studying this subject is understanding the transmission patterns and speed of a crisis in diverse economic conditions, sectors and/or countries. These insights could prove invaluable when attempting to forecast the effects of future crises. They could be used to design and implement useful strategies that lead to a sustainable development.

This paper investigates the impact of the Global Financial Crisis (hereafter, GFC) on various real economy sectors from Poland (chemical, construction, food industry, media, IT, oil and gas, telecommunication). The Polish economy is said to be one of the least affected by the GFC in Europe (Leven, 2011) as it was the only EU countries to register an increase of GDP in 2008. However, Adamowicz and Adamowicz (2019) show that the GFC has impacted various economic aspects of this market, "not only the banks and financial institutions, but also enterprises, households, budgets and public finances". But its effects were delayed (from 2007 - the beginning of the US crisis to the end of 2008 - 2009) and less intensive due, at least in part, to the implemented anti-crises measures. Nonetheless, the authors show that the crisis' effects included a steep decline in 2008 of four general stock market indices, followed by a recovery in 2009 and 2010. Additionally, the domestic demand decreased in 2009, while the budget deficit and the financing costs increased which lead to a higher unemployment rate. Based on these observations, this paper analyzes the real-economy sectors separately to individualize the crisis contagion pattern for each of them.

While GFC had financial underpinnings, the Covid-19 Pandemic is, primarily, a healthcare problem. Thus, a direct connection between the impact that these two global crises have on the economic environment is hard to establish. However, the necessary lockdowns and social distancing measures specific to the Covid-19 Pandemic had an important impact on the financial and real economy sectors, similar to the GFC implications. Phan and Narayan (2020) showed

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the devastating effects these measures had on the stock markets and suggested the presence of overreaction during the initial turmoil and a subsequent correcting behavior. Choi (2021) studied the impact of the GFC and the Covid-19 Pandemic on 11 American economic sectors (from S&P 500). He concluded that the two crises had a similar influence on the market efficiency level of the sectors.

The Polish sectors studied in this paper seem to have also been impacted by the Covid-19 Pandemic. A simple statistical analysis (as seen in Appendix 1) suggests that the Polish sectors had a similar evolution during the two global crises (e.g. the financial sector is the one with the highest decrease during both crises, while the oil and gas sector registered the highest recovery during the analyzed period). This signals that conclusions obtained through the study of the GFC could provide some insight about the development of the financial contagion process during this more recent crisis.

The Polish real-economy sectors were studied based on the evolution of their stock indices constructed on Warsaw Stock Exchange. The analyzed period is January 2000- December 2019. The extended timeframe of the database is meant to provide sufficient information about the evolution of these sectors in both crisis and non-crisis situations. Thus, the GARCH methodology employed to determine the actual length of the GFC (through excess volatility) is more robust.

As the GFC was, initially, a crisis of the financial industry, the possible transmission channels taken into consideration were the domestic and foreign financial sectors. The crisis period definition considers multiple temporal lengths: determined by the crisis presence on the US market, the global financial sector, the overall global market, the whole Polish market and specific to the seven real-economy sectors. The results do not change significantly by including different definitions for the crisis period, signaling their robustness.

The results show that the construction and oil & gas sectors are the most affected by GFC and the transmission channel was, mainly, through the domestic financial sector. The food industry was also impacted by the crisis, through the foreign financial sector, but the magnitude was insignificant. The IT and telecommunication have registered a decrease of co-movements during the GFC with both the foreign and domestic financial sectors, while the chemicals and media sectors have negative coefficients only with the foreign financial. Similar conclusions were drawn in existing financial literature, for other markets (among others, Baur, 2012; Samitas et al., 2020). This suggests that , during the GFC, a real-economy sector exhibited similar behaviors across different markets.

The results show that most, but not all, of the analyzed Polish sectors were not affected by the GFC through the turmoil present on the domestic or foreign financial systems. This is in line with Adamowicz and Adamowicz (2019) which noted that the effects of the crisis could be observed on the Polish market, even though they were reduced. These conclusions can be useful for investors, as they suggest that a diversification strategy might be profitable, by including, in the desired international portfolio, sectors that exhibit a lower level of integration with the global financial portfolio (Nardo et al., in press).

Additionally, the Polish market could prove an interesting option for foreign portfolio managers, as it is the only one from Eastern Europe that has managed to achieve an upgrade from an emerging to a developed market after the GFC (according to the FTSE classification). The other stock exchanges from the region are either emerging or frontier ones. For this reason, these other capital markets could be interested in the reaction observed on Warsaw Stock Exchange. Thus, they might be able to determine if certain market-specific characteristics can be linked to this achievement in order to try to mimic them.

Academics could also benefit from these results, as they could include the diverse behavior observed in the seven economic sectors in their theories related to market efficiency, trading strategies' usefulness or investor behavior. At least, these conclusions suggest that analyzing different phenomena on a stock market only at the level of an aggregate, blue-chip index

(most liquid, highest market capitalization) can lead to biased results or ones that cannot be generalized to the whole market.

The remainder of the paper is structured as follows. Section 2 provides a brief review of the existing literature on this subject. The purpose is not to make an exhaustive presentation of financial papers on this theme, as it is a highly studied one, but to offer insight to the usefulness of this study and the gap it fills in literature. Section 3 depicts the methodology employed in the study and section 4 details the database development. Section 5 discuses the results obtained based on the proposed methodology and section 6 draws the main conclusions, based on the given results.

2. Literature review

While there is no universally accepted definition, a high number of studies use the perspective of Forbes and Rigobon (2001) who identify contagion as "a significant increase in cross-market linkages after a shock to an individual country". Another popular one is provided by Claessens et al. (2001) where contagion is "the spread of market disturbances, mostly on the downside, from one country to another". The two are very similar, but the second one offers more insight in what could constitute a shock. It suggests that shocks can include both negative or positive occurrences on a market that leads to a deviation from its average, day-to-day development.

Numerous papers have analyzed the financial contagion process during the GFC at an aggregate level, by taking into account either national capital markets or regional markets. Warsaw stock exchange is included in many such studies, either through its general index or as part of the European markets.

Horvath and Petrovski (2013) showed that, on average, markets from Central Europe (Czech Republic, Hungary and Poland) are more integrated with Western Europe (evaluated through the STOXX Europe 600 index) as opposed to South Eastern Europe (Macedonia, Croatia and Serbia) where the comovements are "essentially zero". Nardo et al. (in press) investigate market integration across the EU28 markets. They find increased integration during the sovereign debt crisis which is primarily driven by macroeconomic variables, market capitalization and political uncertainty. Additionally, they prove that higher market integration leads to less effective portfolio diversification strategies.

Tilfani et al. (2019) studied Poland (and other European markets) and its integration with major stock markets (China, Germany, Russia, UK and USA). Results showed high correlation between Poland and the five developed markets, the highest being with Germany and the lowest with China. Moreover, the correlation increased during crisis periods, but it decreased after the Brexit. This increased market segmentation could show uncertainty and fear among investors. According to the authors, "if investors want to diversify their portfolios, they should choose investments in segmented markets". By employing a different approach, Jareno et al (2021) obtain similar conclusions for the Polish market: it presents positive interdependencies with the German, British, American and Chinese markets. Additionally, the results show long-run symmetry and short-run asymmetry in the markets' behavior to changes.

Some papers have argued that analyzing a country's response to a specific phenomena at a general, aggregate level can generate misleading results. That conclusion appears to be somewhat intuitive, given the fact that real-economy sectors are influenced differently by macroeconomic factors (Belgrave et al, 2012). This can be linked to the specific characteristics of the sector: elastic versus inelastic demand or supply, degree of technological advancement, need of highly trained human capital, export possibilities (Hess, 2003).

Studies have shown that the reaction of a country to an outside shock is not, necessarily, the same across the whole economic environment of that country. Baur (2012) examined the spread of the GFC to several real-economy sectors from 25 developed and emerging stock markets through the domestic or foreign financial sector. It showed that every market and sector showed signs of contagion. However, the impact of the crisis can be differentiated, some sectors (healthcare, telecommunications, technology) being less affected than others. Moreover,

some sectors have registered more often an impact of foreign contagion (utilities), while others were influenced by a domestic one (consumer services).

Table 1. Summary of similar papers' results

Article	Studied region / sectors	Methodological approach	Period	Results
Baur (2012)	25 countries* / Oil & Gas, Materials, Industrials, Cons. goods, Healthcare, Cons. services, Telecomm., Utilities, IT, Financials	GJR-GARCH model	Oct. 1979 - Oct. 2009	most cases of domestic contagion are in emerging markets; most cases of foreign contagion are in developed markets
Kenourgious and Dimitriou (2014)	US, developed Europe* / Energy, Materials, Industrials, Cons. goods, Healthcare, Cons. services, Telecomm., Utilities, IT, Financials	GJR-GARCH model	Jan. 2004 - Dec. 2009	global financial contagion in all US sectors and European consumer services and healthcare sectors; no evidence of domestic financial contagion
Kenourgious and Dimitriou (2015)	6 regions / Energy, Materials, Industrials, Cons. goods, Healthcare, Cons. services, Telecomm., Utilities, IT, Financials	FIAPARCH model	Jan. 2004 - Dec. 2010	most sectors are immune to shocks in the first crisis phase; in phase 2 and 3 most cases of contagion are present
Gencer and Demiralay (2016)	emerging Europe - aggregated index / Cons. discretionary, Cons. staples, Financials, Energy, Healthcare, IT, Industrials, Materials, Telecomm., Utilities	GJR-GARCH	Jan. 2001 - Dec. 2013	the real economy sectors display co-movements during both the GFC and the European Sovereign Debt crisis
Chen et al. (2020)	20 countries* / Energy, Materials, Industrials, Cons. goods, Cons. services, Healthcare, IT, Telecomm., Utilities, Financials	GJR-GARCH, expanding Baur (2012) model with spatial econometrics and complex network	Apr. 2008 - Dec. 2014	global financial sector contagion is present in the US, China and European countries; real economy sectors in developed markets are more vulnerable to global contagion, while those from emerging markets are vulnerable to the domestic financial sector
Samitas et al. (2020)	8 countries* / Oil & Gas, Basic Materials, Industrials, Cons. goods, Healthcare, Cons. services, Telecomm., Utilities, IT, Financials	ADCC model and copula functions	Jan. 1998 - Dec. 2015	UK sectors are the most correlated with Eurozone countries; Telecommunications, Utilities and IT; weak contagion effects

Note: * signals that Poland was not included in the database; Cons. stands for "consumer" and Telecomm. stands for "Telecommunications".

These results are supported by Samitas et al. (2020) which also employ additional methodologies (the ADCC model and various copula functions) through two major crisis periods (the Subprime crisis and the Eurozone Debt crisis). Furthermore, they show that, only during the Subprime crisis and only for Oil&Gas and Basic materials sectors, a pure contagion can be depicted.

Following the methodology of Baur(2012), Kenourgious and Dimitriou (2014) have studied the aggregate regional indices of USA and developed European markets. Their results show that all US sectors were influenced by global contagion, with no significant values for domestic contagion. The European region registered global contagion only for two sectors: consumer goods and services, and, similar to USA, no domestic contagion.

Kenourgious and Dimitriou (2015) study the spread of the GFC through nine real-economy sectors from six geographical regions (USA, Developed Europe, Emerging Asia, Developed Pacific, Latin America and Emerging Europe) by employing a multivariate FIAPARCH model. Their results show clear differences between the analyzed sectors and regions. Developed Pacific showed no signs of global contagion and moderate impacts of domestic contagion on four sectors. However, Emerging Asia was influenced by a global contagion in six of the nine sectors, and regional contagion in all of them. When assessing the economic perspective, the Energy sector is the one most often impacted by either type of increased co-movements, while the Materials sector showed signs of contagion in only a few regions.

Gencer and Demiralay (2016) use the methodology of Baur (2012) to determine the spread of the GFC and the European sovereign debt crisis (ESDC) throughout emerging markets' economic sectors seen at a regional level. As possible transmission channels, they take into consideration three options: the US financial sector, the European financial sector and the Emerging Markets financial sector. According to their results, the European financial sector is the main source of contagion for the energy, materials and industrial sectors during the ESDC, but the healthcare system is more vulnerable to the Emerging markets financial contagion during both crises.

Chen et al. (2020), developing the model of Baur(2012), include in the methodology spatial spillover and industry aggregation effects. Their database includes the top 20 countries as GDP and analyzes the spread of the GFC. Their results show that the epicenter of the crisis was the financial sector and that spatial effects exist between the financial and non-financial sectors. Additionally, their conclusions state that global contagion can be observed only for the US and European markets, but not in China. The latter's real economy sectors are infected through the domestic financial sector.

A brief summary of the results obtained by papers that studied the financial contagion process in the real economy sectors is presented in Table 1. To the best of my knowledge, the Polish sectors were not studied individually in other papers. The present paper endeavors to fill this gap.

3. Methodology

This paper's methodology is based on the model proposed by Baur (2012), as an extension to the one employed by Bekaert et al. (2005), used to distinguish between domestic and foreign contagion during the financial crisis, as presented in equation(1):

$$R_t = a + b_1 \times R_{FIN\_W_t} + b_2 \times R_{FIN\_W_t} \times D_c + c_1 \times R_{FIN\_D_t} + c_2 \times R_{FIN\_D_t} \times D_c + \varepsilon_t \quad (1)$$

where R_t is the daily return of the non-financial sector index, $RFIN\_W$ is the daily return of the world financial index, $RFIN\_D$ is the daily return of the Polish financial index and D_C is a dummy variable that describes the crisis period (it takes the value 1 during the period of the GFC and 0 otherwise). a, b_1, b_2, c_1 and c_2 are coefficients to be determined. According to Baur (2012), if either b_2 or c_2 are positive, it proves the existence of contagion: a positive b_2 shows an increase co-movement between the Polish non-financial sector and the world financial

sector (foreign contagion), while a positive c_2 depicts an increase in the co-movement between the non-financial and financial Polish sectors (domestic contagion).

The presence of heteroskedasticity in data was taken into consideration, by employing a GJR-GARCH methodology, as proposed by Glosten et al.(1993). This framework tests the existence of an asymmetrical response to positive and negative shocks. According to Brailsford and Faff (1996), it is one of the best suited to model volatility on stock markets, especially during crisis periods. The GJR-GARCH (1,1) is studied through the following equation:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \times \varepsilon_{t-1}^2 + \beta \times \sigma_{t-1}^2 + \gamma \times \varepsilon_{t-1}^2 \times I_{t-1} \tag{2}$$

where σ_t^2 is the conditional variance of return at time t, ε_t is a discrete-time stochastic variable, I_{t-1} is a dummy variable which takes the value 1 if ε_{t-1} <0 (indicating bad news) and 0 otherwise. The α_1 parameter indicates the short-run persistency of shocks and β depicts the long-run persistency. The γ parameter depends on the asymmetric impact of shocks: a non-zero value implies an asymmetric response to positive and negative shocks (Brooks 2008, 405), while a zero value for this parameters leads to a classical GARCH (1,1) model. The GJR coefficients are presented in Appendix 2.

Furthermore, as a development to the model proposed by Baur(2012), the methodology uses a t-student distribution of residuals to model their non-normality and an ARMA process to correct their autocorrelation (similar to the methodology Sewraj et al., 2019). By employing an ARCH LM test, no additional ARCH effects were detected.

4. Database

The database consists in the daily returns of the main sector indices from the Polish market: banking (hereafter, BNK), chemical (CHEM), construction (CNST), food industry, IT, media, oil and gas (OIL), telecommunication (TEL). They were provided by Thomson Reuters Database and include companies listed on Warsaw Stock Exchange from these respective industries. The main descriptive statistics are presented in Table 2. In order to differentiate between domestic and foreign financial contagion, the BNK index was used as a proxy for the domestic financial sector and the Thomson Reuters Global Financials Index for the global one.

Table 2: Descriptive statistics

Index	Mean	Median	Max.	Min.	Std. Dev.	No. obs.	% missing days	Start date
BNK	0.02%	0.00%	9.19%	-13.19%	0.0150	5188	0.00%	08.02.2000
CHEM	0.04%	0.00%	8.92%	-9.86%	0.0166	2938	4.15%	23.09.2008
CNST	0.01%	0.00%	8.55%	-8.04%	0.0129	5188	4.03%	08.02.2000
FOOD	0.02%	0.00%	9.89%	-11.17%	0.0130	5188	4.03%	08.02.2000
IT	0.01%	0.00%	8.15%	-10.48%	0.0148	5084	3.99%	03.07.2000
MEDIA	0.03%	0.00%	6.92%	-10.18%	0.0140	3908	4.07%	04.01.2005
OIL	0.03%	0.00%	10.35%	-8.93%	0.0171	3648	4.11%	03.01.2006
TEL	-0.01%	0.00%	9.30%	-24.57%	0.0169	5084	3.99%	03.07.2000
FINW	0.01%	0.04%	11.38%	-8.04%	0.0108	5188	0.00%	08.02.2000

Source: Own calculation. The abbreviations are as follows: BNK for the banking sector, CHEM for the chemical sector, CNST for the construction sector, FOOD for the food industry, IT for the IT sector, MEDIA for media industry, OIL for the oil and gas sector, TEL for the telecommunication industry and FINW for the world financial sector. Max refers to the maximum level, Min to the minimum one, Std. Dev. refers to standard deviation and No.obs. registers the number of observations in the database for each index.

As the crisis period might significantly influence the obtained results, several perspectives were used to define it. Firstly, I considered as a crisis period (D_us) the days when the US market was under pressure through the announcements of general negative financial and

economic news, as determined by the Federal Reserve Board of St. Louis (2009) and the Bank for International Settlements (BIS, 2009).

Additionally, I took into consideration the days with a high market volatility as a crisis period based on the assumption that, during the crisis, the uncertainty level increases and leads to higher price volatility. For this, similar to Baur(2012), I employed a GARCH methodology to forecast the daily volatility on the market for the whole period present in the database. Based on these values, to pinpoint the exact crisis period specific to the stock market, I determined which of the days registered a higher volatility than the 90% quantile of the series. In order to ensure that the high volatility was caused by the GFC and not by other crises or by episodes of market optimism, I considered the days with high volatility observed immediately after the beginning of the crisis period on the US crisis (August, 1st, 2007).

I employed this methodology on several different indices: the Thomson Reuters Global Financials Index (D_finw), the Thomson Reuters Global Index (D_wrd) and the WIG20 index (D_wig). Because the economic sectors included in the database would, presumably, react differently to the global crisis, I decided to also determine the crisis period, using the GARCH methodology, for each sector (D_sector). The crisis periods thus obtained are presented in Table 3. It shows a big length difference between some sectors (e.g. CNST and OIL). This can be explained by the large differences in the evolutions of the daily volatility series between sectors, as shown in Appendix 3. Using different definitions for the crisis period offers robustness to the results, as stated in Kenourgious and Dimitriou (2014).

Table 3. Crisis period

	D_wig	D_us	D_wrd	D_finw			
Start date	30.09.2008	01.08.2007	05.09.2008	16.07.2008			
End date	08.05.2009	31.03.2009	07.08.2009	11.09.2009			
D_sector	CHEM	CNST	FOOD	IT	MEDIA	OIL	TEL
Start date	24.09.2008	22.09.2008	16.09.2008	13.10.2008	13.10.2008	13.10.2008	30.10.2008
End date	22.12.2008	24.12.2008	29.12.2008	18.12.2008	24.12.2008	28.08.2009	12.01.2009

Source: Own calculation.

5. Results

The results obtained for the presented methodology are presented in Table 4. Only CNST and OIL register positive and significant values for c_2 which show that these sectors have been influenced by the crisis through the domestic financial sector. They also have negative significant values for b_2, meaning that the relation with the foreign financial sector has decreased during the GFC. These results are consistent with the ones obtained by Baur (2012) for other 25 major developed and emerging stock markets and Samitas et al. (2020).

A similar perspective is obtained for the CHEM and MEDIA sectors. However, their values for the c_2 coefficient are small, signaling that the domestic financial contagion's impact has been negligible. Even though these sectors appear to have very little in common from an economic point of view, the daily volatility series of their indices has a similar pattern (Appendix 3): very high volatilities around 2008, followed by a significant decrease in 2009.

The FOOD sector is the only one that appears to be influenced by a foreign financial contagion, registering positive values for b_2 and negative for c_2. Nonetheless, these coefficients are not significant, suggesting that the impact of the phenomenon on this crucial real-economy sector is relatively small. This is in line with the intuitive assumption, as the food sector is one with an inelastic demand (Hall, 2020).

The IT and TEL sectors have both registered negative values for b_2 and c_2, meaning that they registered a decrease in co-movements with both the domestic and foreign financial sector. This suggests that the link between these sectors and the financial industry was reduced during the crisis. This result supports the conclusion of Baur (2012) and Samitas et al. (2020) that

state that the technology and telecommunication sectors are among those which are less affected by the GFC.

Table 4. Domestic versus foreign contagion on Polish sectors						
Sector	Coeff.	D_wig	D _us	D_finw	D_wrd	D_sector
CHEM	a	0.0002	0.0002	0.0002	0.0002	0.0002
	b_1	0.3182***	0.3116***	0.3129***	0.3120***	0.2927***
	b_2	-0.1165**	-0.1081**	-0.0839	-0.0801	-0.1046
	c_1	0.3477***	0.3473***	0.3511***	0.3587***	0.3482***
	c_2	0.0126	0.0198	0.0029	-0.0271	0.0877
	LLH	8511.12	8510.50	8510.24	8511.03	8509.54
CNST	a	-0.0001	-0.0002	-0.0002	-0.0002	-0.0002
	b_1	0.1760***	0.1687***	0.1693***	0.1681***	0.1520***
	b_2	-0.1215***	-0.0990***	-0.0831***	-0.0821***	-0.0595
	c_1	0.3264***	0.3161***	0.3243***	0.3278***	0.3265***
	c_2	0.0420*	0.0957***	0.0344	0.0198***	0.0771
	LLH	16513.68	16514.52	16511.11	16510.96	16226.04
FOOD	a	0.0000	0.0000	0.0000	0.0000	0.0000
	b_1	0.1405***	0.1399***	0.1323***	0.1338***	0.1405***
	b_2	0.0097	-0.0053	0.0588	0.0524	0.0200
	c_1	0.2387***	0.2323***	0.2409***	0.2396***	0.2382***
	c_2	-0.0150	0.0388	-0.0333	-0.0241	-0.0243
	LLH	16160.47	16261.26	16261.36	16261.08	15992.81
IT	a	0.0002	0.0001	0.0002	0.0002	0.0002
	b_1	0.1895***	0.1964***	0.2005***	0.1949***	0.1631***
	b_2	-0.1502***	-0.1467***	-0.1589***	-0.1471***	-0.0679
	c_1	0.3583***	0.3523***	0.3592***	0.3602***	0.3582***
	c_2	-0.0093	0.0248	-0.0020	-0.0116	-0.0026
	LLH	15627.36	15626.17	15629.67	15628.42	15619.3
MEDIA	a	0.0002	0.0001	0.0002	0.0002	0.0002
	b_1	0.1716***	0.1893***	0.1855***	0.1798***	0.1375***
	b_2	-0.1441***	-0.1810***	-0.1552***	-0.1397***	0.0364
	c_1	0.3625***	0.3448***	0.3576***	0.3638***	0.3696***
	c_2	-0.0215	0.0655**	0.0060	0.0015	-0.0612
	LLH	11898.50	11898.75	11898.80	11882.32	11871.66
OIL	a	0.0001	0.0001	0.0001	0.0001	0.0001
	b_1	0.2878***	0.3188***	0.2994***	0.2944***	0.2795***
	b_2	-0.2401***	-0.2729***	-0.2212***	-0.2218***	-0.1958***
	c_1	0.5437***	0.5289***	0.5410***	0.5395***	0.5433***
	c_2	-0.0035	0.0797**	0.0257	0.0331	0.0181
	LLH	10670.17	10673.61	10669.75	10668.77	10665.79
TEL	a	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
	b_1	0.0689***	0.0837***	0.0817***	0.0765***	0.0595***
	b_2	-0.0777**	-0.1035***	-0.0914**	-0.0819**	-0.1875**
	c_1	0.4350***	0.4325***	0.4441***	0.4392***	0.4208***
	c_2	-0.1107***	-0.0392	-0.1246***	-0.1183***	0.1459*
	LLH	14687.77	14686.35	14693.68	14690.53	14682.73

Source: Own calculation. ***, ** and * show a 1%, 5% and 10% significance level. LLH refers to the log likelihood indicator. A higher value is desired as it suggest a better model to describe the evolution of the sector index.

Additionally, in IT, the main decrease was registered in connection with foreign contagion, while, in TEL, the situation is reversed. This, in connection with the values of b_1 and c_1, suggests that the main funding connection for these sectors was, both in crisis and non-crisis periods, the domestic sector.

Based on Table 4, the reaction of the seven main Polish economic sectors to the GFC has been significantly different. However, it can be seen that using different definitions of the crisis does not lead to significantly different results within the economic sector. This signals the robustness of the conclusions that were drawn (Kenourgious and Dimitriou, 2014).

Additionally, the LLH indicators show that the best definition of the crisis period differs between sectors. The CNST and OIL sectors seem to have been in crisis the longest, during the period that the US market has been under pressure (D_us). The rest have suffered from the crisis in the same period as the global financial sector (D_finw), with the exception of the chemical sector, which has been affected alongside the general Polish market (D_wig).

6. Conclusion

Financial contagion has been an important subject in economic literature. It represents, as a general concept, the transmission of shocks (usually negative ones) from one country to the other (Claessens et al., 2001). Studies have shown that a shock's transmission from one country to another is not similar across the whole economic environment. Some sectors have a bigger reaction to the shock, which translates to a higher increase in the sector's co-movements, while other's behavior shows little to no change (which can sometimes include a decrease of linkages). Additionally, studies have determined that the transmission channel of the crisis can be either domestic or foreign contagion.

This perspective is taken into consideration in this paper by studying the transmission of the GFC on seven Polish economic sectors: chemical, construction, food industry, media, IT, oil and gas, telecommunication. As the crisis has started in the financial industry, the considered transmission channels are the foreign and domestic financial sectors. The length of the crisis periods includes multiple perspectives, linked to the presence of the crisis on the US market, the global financial sector, the overall global market, the Polish market and specific to each of the analyzed sectors.

On a first glance, the Polish market, viewed as a whole, showed to be less impacted by the GFC than other European countries. However, this pattern can be the result of the fact that the GFC has impacted the sectors of the Polish economy in different ways (e.g. some economic sectors were affected by this phenomenon, while others were sheltered or the crisis affected the sectors at different times). If that is the case, then, when looking at the entire Polish market, the impact of the GFC could be harder to observe. This study can be used to avoid this problem, by studying the individual impact of the GFC on the real-economy sectors. Moreover, it differentiates between global and domestic contagion, providing the possible transmission channel of the crisis. And it signals which sectors should respond better to the nationally developed containment strategies (e.g. sectors that have been primarily affected by a domestic contagion).

The results show that the construction and oil& gas sectors are the most affected by GFC, through domestic contagion. However, the IT and telecommunication sectors register a decrease in co-movements. These results are in line with, among others, the study of Samitas et al (2020) employed on other capital markets, suggesting that the contagion process registered similar patterns in sectors from different economic environments. Additionally, the crisis length is different in these real-economy sectors, meaning that, in some periods, the impact of the GFC was present on some sectors (construction and oil & gas), while others were crisis-free.

These diverse behaviors suggest that portfolio diversification is possible when including the Polish market in the trading strategies. Thus, potential investors could consider adding stocks from some of these sectors in their international portfolios. This supports the findings of Tilfani et al. (2019) and Jareno et al (2021) which suggest that significant interdependencies between

markets should be considered when creating efficient portfolio strategies. While it is not the scope of this study to propose possible investment strategies, it offers insight in the behavior of individual sectors during turbulent times. Thus, it can be used in developing future research studies connected with this topic.

Furthermore, the model presented in the article can be adapted to investigate other crises that affected the region or, even, the global markets by tailoring it to the specifics of each crisis. It can include as possible transmission channels not only the financial sectors, but other real-economy sectors (e.g. healthcare, pharmaceuticals or oil markets). Thus, the global financial distress resulted from the oil crash of 2018 or the COVID-19 pandemic can be the subject of future research.

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7. Appendices

7.1. **Appendix 1. Sector evolution during crisis: GFC versus Covid-19 Pandemic.**

Polish sector		BNK	CHEM	CNST	FOOD	IT	MEDIA	OIL	TEL
Mean	GFC	-0.03%	-0.03%	-0.09%	0.00%	-0.05%	-0.08%	-0.04%	-0.01%
	Covid-19	-0.04%	0.03%	0.21%	0.12%	0.12%	0.07%	-0.05%	0.04%
Median	GFC	0.00%	0.00%	-0.04%	0.00%	-0.02%	0.00%	-0.03%	0.00%
	Covid-19	-0.17%	-0.23%	0.18%	0.06%	0.04%	0.03%	-0.04%	-0.06%
Maximum	GFC	9.19%	8.92%	6.88%	9.89%	6.44%	6.92%	10.35%	7.33%
	Covid-19	9.72%	10.74%	7.48%	11.20%	4.90%	8.79%	12.10%	11.09%
Minimum	GFC	-13.19%	-8.75%	-7.83%	-7.39%	-8.44%	-10.18%	-8.93%	-6.05%
	Covid-19	-15.15%	-11.57%	-6.90%	-11.15%	-7.28%	-9.23%	-8.93%	-9.29%
Std. Dev.	GFC	2.78%	2.27%	1.72%	1.83%	1.69%	1.90%	2.42%	1.82%
	Covid-19	2.65%	2.52%	1.71%	1.87%	1.53%	2.14%	2.48%	1.88%

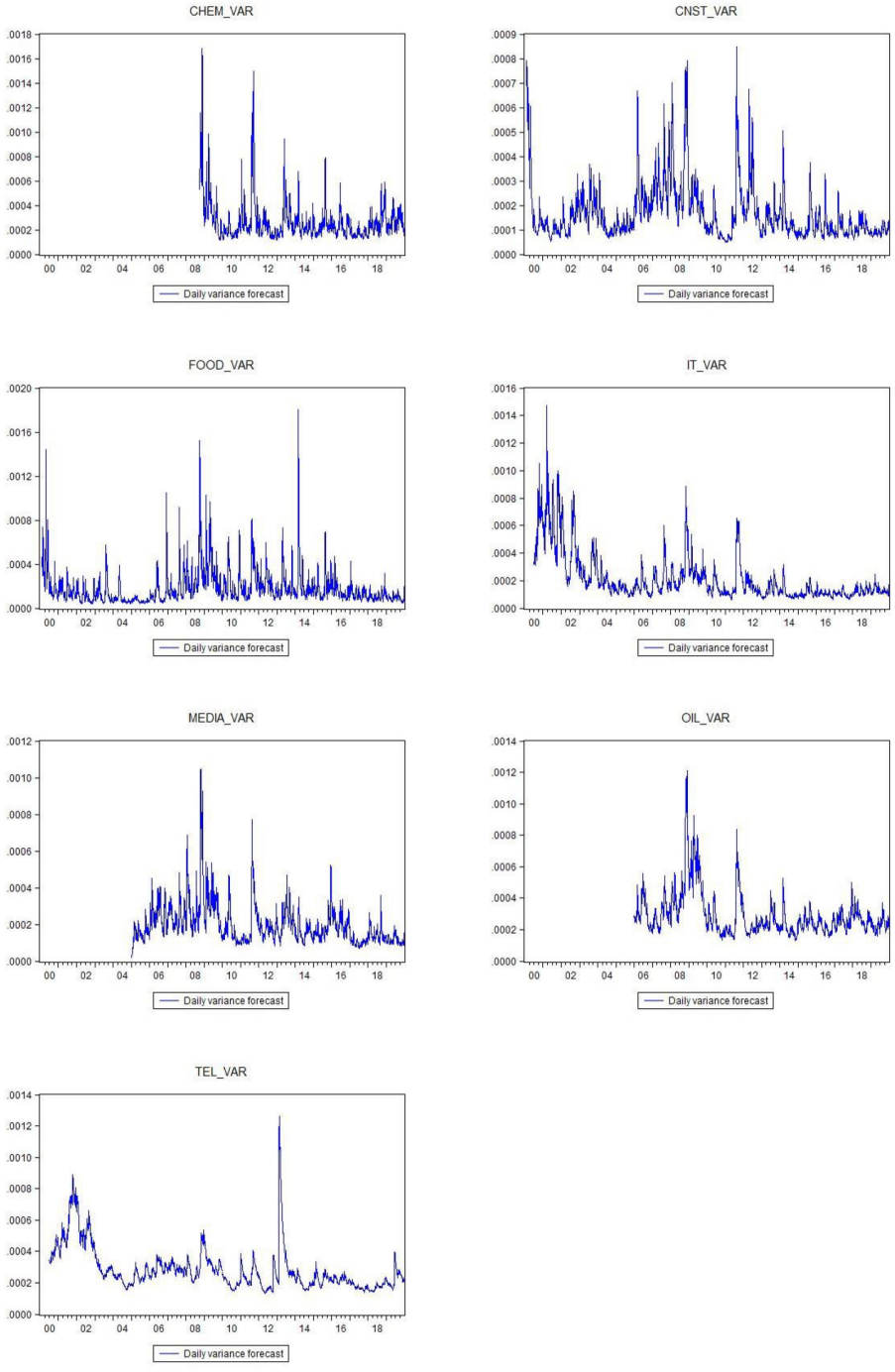
Source: Own calculation. Data for the COVID-19 period is provided by Investing.com

7.2. **Appendix 2. GJR-GARCH coefficients.**

Sector	Coeff.	D_wig	D_us	D_finw	D_wrd	D sector
CHEM	α_0	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
	α_1	0.0478***	0.0487***	0.0475***	0.0475***	0.0450***
	γ	0.0369**	0.0374**	0.0362**	0.0361**	0.0355**
	β	0.8913***	0.8896***	0.8933***	0.8930***	0.9002***
CNST	α_0	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
	α_1	0.0520***	0.0474***	0.0483***	0.0490***	0.0459***
	γ	0.0265**	0.0345***	0.0337***	0.0338***	0.0353***
	β	0.9142***	0.9149***	0.9141***	0.9130***	0.9176***
FOOD	α_0	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
	α_1	0.0827***	0.0822***	0.0823***	0.0821***	0.0811***
	γ	0.0410**	0.0410**	0.0414**	0.0415**	0.0378**
	β	0.8781***	0.8793***	0.8785***	0.8788***	0.8819***
IT	α_0	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
	α_1	0.0376***	0.0375***	0.0373***	0.0375***	0.0378***
	γ	0.0144	0.0159*	0.0142	0.0142	0.0156*
	β	0.9450***	0.9442***	0.9455***	0.9453***	0.9445***
MEDIA	α_0	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
	α_1	0.0715***	0.0678***	0.0709***	0.0680***	0.0679***
	γ	0.0597**	0.0550**	0.0531**	0.0549***	0.0483***
	β	0.7567***	0.7783***	0.7664***	0.7654***	0.7881***
OIL	α_0	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**
	α_1	0.0282***	0.0284***	0.0289***	0.0285***	0.0289***
	γ	-0.0044	-0.0045	-0.0055	-0.0051	-0.0057
	β	0.9671***	0.9668***	0.9668***	0.9670***	0.9671***
TEL	α_0	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
	α_1	0.0637***	0.0653***	0.0641***	0.0622***	0.0648***
	γ	0.0148	0.0138	0.0154	0.0149	0.0108
	β	0.9028***	0.9017***	0.9004***	0.9042***	0.9057***

Source: Own calculation. ***, ** and * show a 1%, 5% and 10% significance level.

7.3. **Appendix 3. Daily variance forecasting.**



Source: Own calculation. The bottom axis represents the date (between January 2000 and December 2019) and the left axis is the daily variance forecasted through the GARCH methodology.