THESISES OF THE DOCTORAL (PhD) DISSERTATION

TIME-VARYING SPILLOVERS BETWEEN AGRICULTURAL COMMODITY MARKETS

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1. BACKGROUND, OBJECTIVES AND PRESENTATION OF THE RESEARCH HYPOTHESES

The final topic of my doctoral studies was substantially affected by my interest in complex systems, so I started to study multivariate time series econometric models. However, I found confusing, that these models were not, in many cases, realistic. It was especially problematic, that the models routinely did not take time-dependent relationships into account. This problem was partly corrected by DIEBOLD – YILMAZ (2012) and their index, which was able to measure the so-called time-varying spillovers. Spillovers are calculated from a vector autoregressive model (VAR) by the decomposition of the forecast error variance. This is a flexible approach, where spillovers can be analysed in a multivariate context. My primary research was empirical due to two specific reasons. First, there was no widely accepted theory to explain the volatility effects, while the already present models performed badly empirically in most of the cases. This was partly the reason behind the many interpretation of the commodity market relationships in the past decade (WRIGHT, 2011). Second, the JUSELIUS (2006) and JOHANSEN (1995) type of „data driven" approach seemed to be a better fit, since it allows the data to „speak." Since there has been no comprehensive theoretical model of the Hungarian commodity market interactions, this approach provided greater flexibility in terms of data analysis.

The topic has become increasingly relevant in the past few years, since risk management became a major theme in the agricultural policy of the European Union, while price support was replaced by direct payments, allowing the policy became more market orientated (EUROPEAN COMMISSION, 2017b). Due to the stronger market integration, production and income-centricity have come to the fore instead of the traditional volume-based approach (POPP et al., 2018). The agricultural foreign trade has been intensified for several agricultural commodities. Accordingly, the price formula has been increasingly determined by world price levels in the EU. This, together with the rise of direct subsidies, has resulted in market prices being able to move over a wider range, thus increasing price volatility (EUROPEAN COMMISSION, 2017b). Most research agreed that price volatility increased after 2000 (GILBERT – MORGAN, 2010a, GILBERT – MORGAN, 2010b, WRIGHT, 2011, JI – FAN, 2012, BRÜMMER et al., 2013, GARDEBROEK – HERNANDEZ, 2013, EUROPEAN COMMISSION, 2015, 2017b), which was mainly the result of a marketoriented agricultural policy, but a number of other factors also contributed to the higher risk (EUROPEAN COMMISSION, 2017b). In the commodity market, there was strong evidence that volatility spillover level has increased in addition to price fluctuations (BALCOMBE, 2009).

Research on price volatility has mainly focused on increasing market risk and its distribution (EUROPEAN COMMISSION, 2017a, IYER et al., 2019). This was necessary because the restructured agriculture policy has increased the exposure of actors in the food chain to the world market, thus increasing the measurable risk in the related internal markets due to fluctuating international prices (GOHIN – ZHENG, 2020). To date, the literature has not been able to fully explain the role of certain factors in price increases and price volatility. Most research agreed that changes in market fundamentals (supply and demand) did not provide a sufficient explanation (TADESSE et al., 2014). Other possible causes included the impact of the energy market and the financial sector, the associated speculative effect, trade restrictions and climate change. The problem was exacerbated by the fact, that according to PAL – MITRA (2017) the results of scientific publications were also often contradictory. GILBERT – MUGERA (2019) add that it is challenging for policy to decide which area to focus on, as the results were often elusive. Current risk management tools are only partially able to manage the price and income-based risks and even the availability and adoption of related risk management tools has been lagging behind. EU producers are therefore still exposed to changes in market risk. Risk management is mainly done through individual on-farm strategies, while some instruments of the CAP (for example direct support) and other Member States' risk management policies (like fiscal and tax incentives) indirectly help producers (EUROPEAN COMMISSION, 2017b). For this reason, a comprehensive analysis of this area is clearly relevant.

The main objectives of the research

1) **Outline a framework for the complex interactions in the commodity market.** This step was also crucial because, in the absence of a formal framework, model building had to be based on empirical evidences. In the course of the objective, possible causes behind price volatility and its spill-over effects had to be outlined. Did fundamental fluctuations or mainly temporary factors (energy market, financial market) trigger price fluctuations?

2) **To determine the strength and direction of the spillover effect of oil price fluctuations.** In the case of both primary and secondary research, I examined the extent to which oil price fluctuations affected changes in agricultural raw materials. In addition, I also reviewed the empirical results related to oil price changes after 2010.

3) **To review the results of empirical research related to price fluctuations after 2010.** The results highlighted how different price volatility and spillover effects may be over time and that dependence on local factors was also high.

4) **To determine the factors of price setting in the case of domestic raw material production, processing and trade.** During the analysis, I reviewed the differences in concentration measurements and individual characteristics of the phases of the vertical value chain to determine the shift in market bargaining power and the direction of price transmission. I reviewed the structure and peculiarities of the EU and Hungarian agricultural risk management systems. I have defined the primary purpose of the current agricultural risk management systems. Furthermore, this chapter addressed the possible use of commodity exchange-type risk management tools.

The research questions were the following:

1. **Does the volatility spillover effect between commodity markets change over time?**
2. **Which factors can contribute to the time-varying volatility spillovers?**
3. **What are the risks of the changing volatility spillover effect and what tools can be effective in mitigating the risk?**

Instead of hypotheses, I formulated research questions due to the lack of formal framework for the analysis from which quantifiable hypotheses could be derived. In the absence of preliminary research, instead of hypotheses, I sought answers to general questions that could provide a starting point for examining more quantified hypotheses.

2. DATABASE AND DESCRIPTION OF THE METHODS USED

The calculations were performed in R, mainly using the *vars*[1] and the *frequencyConnectedness*[2] packages and my own codes. In the dissertation, I used the DIEBOLD – YILMAZ (2012) spillover index with differentiated vector autoregression (DVAR) models.

2.1. The methodology used

DIEBOLD – YILMAZ (2009) developed a spillover index based on variance decomposition. The index is based on an *n*-variable *p*-order covariance stationary DVAR model (1):

$$x_t = \sum_{i=1}^{p} \Phi_i x_{t-i} + \varepsilon_t \quad (1)$$

Where x_t was the analysed price in time t, Φ_i is the parameter matrix, while ε_t was the independently and identically distributed error term with $\varepsilon_t \sim IN(0, \Sigma)$. The forecast error can be broken down into own and cross variance shares The spillover index measures the ratio of own and cross variance in the variance of the total forecast error, expressed as a percentage. The result of the variance decomposition depends on order imposed by the Cholesky decomposition. Thus DIEBOLD – YILMAZ (2012) improved the index with the PESARAN – SHIN (1998) generalized variance decomposition. The VD of the error of the H-period forecast was denoted by $\theta_{ij}^{g}(H)$, so that for $H=1, 2 \ldots$[3]:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h \Sigma e_j\right)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)} \quad (2)$$

Where σ_{jj} is the standard deviation of the error of equation j, Σ is the variance covariance matrix of the error ε_t, e_i is a simple selection vector that takes 1 at position i and is otherwise

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[1] vars package: https://CRAN.R-project.org/package=vars
[2] frequencyConnectedness package: https://CRAN.R-project.org/package=frequencyConnectedness
[3] The original inscription incorrectly contains σ_{ii}^{-1} n the counter.

zero. The matrix A_h comes from the moving average representation of the VAR. If we perform the following normalization:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)} * 100 \tag{3}$$

The sum is $\sum_{j=1}^{N} \tilde{\theta}_{ij}^{g}(H) = 1$ and $\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H) = N$.

Several indicators can be calculated using the above relationships. The **total spillover index** measures the proportion of variance in the prediction error that results from cross-effects.

$$S^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} * 100 \tag{4}$$

In addition to the full spillover index, there are a number of other indices that also determine the direction of the connection, in both static and dynamic (running window) form. These shed light on the relationship between a given raw material and other markets, or between two individual raw materials. In addition, I also examined the cointegration between variables using the robust method of CHENG – PHILLIPS (2009). The advantage of this method over the traditional JOHANSEN (1995) method that it is robust to some of the error term problems (for example heteroscedasticity), thus more efficient in case of volatile commodity prices.

2.2. Database used and the volatility measurement

The data were measured at daily frequencies from 2005.08.01. to 2018.08.31. The starting date was determined by the availability of the data and the ending date was the time of the last available BSE feed maize price. In all cases, I converted the data to tons (except for Brent crude oil and the HUF / EUR and USD / EUR exchange rates) and Euros.

The conversion of daily USD prices to Euro:

$$p_{i,EUR} = \left(p_{i,USD} * conversion\ constant\right) * \frac{1}{\frac{USD}{EUR}} \quad (5)$$

Logarithmic returns were, by definition, the difference between logarithmic prices $\Delta x_t = 100(\ln(x_t) - \ln(x_{t-1}))$, where x_t was the price on a given day, x_{t-1} was the price the day before, while ln denoted the natural logarithm. Using the conversion constant, I converted the amount of CBOT measured in bushels to tons (for raw materials already measured in tons or barrels, the conversion factor constant was 1). Thus, I was able to continue working with data consistent in both currency and quantity.

Table 1: Data used in the analysis

Data	Type	Available period	Source
Maize (BSE)	to the nearest term, (HUF/tons)	2004.01.05 – 2018.08.31	AHDB (2020)
Wheat (MATIF)	to the nearest term, (EUR/ tons)	2005.08.01 – 2019.09.18.	AHDB (2020)
Maize (MATIF)	to the nearest term, (EUR/ tons)	2005.08.01 – 2019.09.18.	AHDB (2020)
Wheat (CBOT)	to the nearest term, (USD/bushel)	2005.08.01 – 2019.09.18.	AHDB (2020)
Maize (CBOT)	to the nearest term, (USD/ bushel)	2005.08.01 – 2019.09.18.	AHDB (2020)
Soybeans (CBOT)	to the nearest term, (USD/ bushel)	2005.08.01 – 2019.09.18.	AHDB (2020)
Crude oil spot price (BRENT)	Europe Brent Spot Price FOB (USD/barrel)	1987.05.27 – 2019.11.04.	EIA (2020)
Variables for the conversions			
HUF/EUR exchange rate	nominal reference exchange rate	2005.08.01 – 2019.09.18.	ECB (2019a)
USD/EUR exchange rate	nominal reference exchange rate	2005.08.01 – 2019.09.18.	ECB (2019b)

Notes: 1) BSE means the Budapest Stock Exchange, CBOT means the Chicago Board of Trade, while MATIF is a former futures exchange in France, called Marché A Terme d' Instruments Financiers.

Source: Own collection (2019)

Weekly returns were achieved by the Friday to Friday changes in logarithmic prices. If Friday was unavailable, the last trading day of the week would be the reference day. This is a common practice in the financial literature, the original DIEBOLD – YILMAZ (2009) study employed the same method as well. To measure volatility, I calculated the Realized Volatility measurement (RV_i). The sum of the squares of the weekly returns gave the Realized Variance and by taking square root, we obtain the Realized Volatility (Realized Standard Deviation). Trading days were denoted by M (usually M = 5).

$$RV_i = \sqrt{\sum_{i=1}^{M} \Delta x_{ti}{}^2} \tag{6}$$

The RV_i measurement has more favorable properties than the also frequently used squared yield or absolute yield. Its distribution is not as skewed, which is also beneficial when calculating the variance decomposition. In contrast to yields, volatility was an autocorrelated process, which also justified the use of the DVAR model.

3. MAIN FINDINGS OF THE DISSERTATION

I have shown that market risk changed over time and was stronger during market crises *(Figure 1.)*. This is consistent with BALLI et al. (2019) who also showed that commodities were more interconnected in times of market crises. This was particularly true of the 2007/2008 crisis and the time of falling oil prices in 2014-2016. Similar results were obtained by CHEVALLIER – IELPO (2013) and SHAHZAD et al. (2018) also.

Figure 1.: The rolling window (100 weeks) spillover index

Source: Own calculation (2020)

The spillover effects of volatility risk were an extremely complex process, which varied over time and depended on market conditions. Foreign trade can be profitable in the case of high market prices and due to stronger trade relations, the flow of information between two regions strengthens. No clear trend in cereal prices may have been due to the fact that the cereals market has been a well-integrated market already, thus was relatively unaffected by agricultural policy changes in this respect. The long-term impact of changing risk levels may be reflected in declining investment and a further decline in willingness to cooperate. The results of the dissertation are in close agreement with WRIGHT (2014) who highlighted that the behavior of global grain prices reflected their substitutability and storability. This was explained indirectly in my dissertation, but competition and substitutability between raw materials may also have considerably influenced the spillover effects of price volatility.

I have shown bidirectional volatility spillover effects between the commodity and crude oil prices, consistent with recent research (KANG et al., 2017, SHAHZAD et al., 2018, DAHL et al., 2019). This was a somewhat surprising result, as the literature most often perceives the price of crude oil as an exogenous variable. That is, crude oil affects most agricultural commodities, but there is no two-way relationship. In the long run crude oil is likely to have an impact on commodity prices, but not necessarily in the short run. Furthermore, the effect on price level and price volatility could considerably differ.

The time-varying spillover effects show that the state of the market depended on the previous period. Therefore, not only dynamic models but also a dynamic agricultural policy should be targeted, that can take action efficiently and quickly in times of market turmoil. I believe that market disruptions will continue to be frequent in the future, as, based on the experience of the last 20 years, a major event occurs every few years, with an even more significant emphasis on expanding risk management tools. The cyclical movement of volatility spillover indices were naturally linked to the results obtained by KRISTOUFEK et al. (2013). According to them, the market could be divided into "high - low" state. At high prices, the number and strength of market network connections increased, while at low prices, the role of some factors declined.

The greening of the CAP and the further rise of environmental concerns raise questions about the future of the raw materials market. One of the most important changes in the last decade has been the rise of the biofuel industry, which has also been driven by environmental considerations. In the future, the impact of these measures may be even more pronounced. Regulations in the plastics industry could also affect the cereals sector as the spread of degradable packaging materials will increase the demand for starch. In addition, the impact of climate and weather change may remain the most crucial factor in shaping agricultural market. Modeling attempts have most often failed to accurately predict medium and long-term events. Using realistic models and better data quality, modeling can provide highly effective guidelines for policy.

Food industry results indicated high concentration at all levels of the supply chain. The stronger bargaining power and demand orientation of the trade and processing segment was noticeable. The opportunities at the producer level were much more restricted. This is in line with the results of the Hungarian agricultural literature. High market concentration suggests that price and risk increases are shifted to the least adaptive segment of the supply chain, thus risk management system has to consider this shift as well. I believe the Hungarian risk management system correctly recognized this problem in the last decade.

In the case of the food industry, the persistent problem of the lack of development and innovation should also be mentioned. The level of food industry innovation in Hungary is moderate. Breakthrough innovations are extremely rare in the industry and innovation stems from incremental, continuous consultation with partners. In the case of processors, product and market innovation were the fastest, while organizational innovation was mainly present in trade. The overall propensity to innovate was highest in trade (TÓTH – FERTŐ, 2017). Incentives should be offered for food companies to create a viable information network with business, scientific and professional partners. This can foster not only innovation but also international expansion (TÓTH – RIZZO, 2020). As it is difficult or impossible to add value to raw materials, innovation money should be invested in building innovative risk management tools.

Some risk management tools do not necessarily require significant capital raising. Virtually free technology developments can also improve the risk exposure of producers. These include proper cost planning, proper use of crop rotation and farm-level data recording and further analysis of it. Increased use of precision farming tools and minimization of production and storage losses could also be a solution, but these technologies have significant cost implications and are therefore not widespread yet. Enhancing management technologies would also be an important criterion. The qualifications of most farmers do not meet with the competitive practices, and operation was mostly based on experience and tradition. MESTERHÁZY et al. (2020) made similar remarks for the grain supply chain.

POTORI – VARGA (2008) drew attention early on to the risk management opportunities offered by derivatives markets. In Hungary, it may not be possible to take advantage of futures trading in the near future, which is well illustrated by the liquidity of the BSE commodity market (and the lack of it since 2018). In major raw material-producing regions, the use of these tools is much more widespread. Thus, in Hungary, other risk management tools should be relied upon. A possible way to achieve this is to increase the proportion of forward contracts, which do not require stock exchange trading, and the parties can tailor the parameters to their individual needs. With the strengthening of producer organizations, contractual price relations could be placed in a natural framework, but cooperation in the entire supply chain is critically low. This, in turn, seems to be a variable that can be changed with appropriate incentives. In theory, they may also be able to provide price security in producer organizations, but there were no data or surveys on whether this was achieved in Hungary. Producer organizations usually provide a modest advantage, but this can be considerably improved if they have retails chain in addition.

This in addition requires adherence to and expectation of contractual discipline. FELKAI – BENE (2016) remarked, that for example in the case of the dairy industry, a difference of a few forints between domestic and export prices was often enough to loosen contractual discipline and suppliers sell raw materials to other parties. The loosening of contractual discipline has also emerged in the literature in the case of the grain industry (FÖLDMŰVELÉSÜGYI MINISZTÉRIUM, 2015). If the producer group succeeds in reducing the price volatility of purchase prices and can play a role in stabilizing income, it could offer a solution in part to deal with time-varying risks. The international literature also supports these proposals. According to VON BRAUN – TADESSE (2012) it is also necessary to strengthen contractual relations and price-related insurance. ASSEFA et al. (2017) also draws attention to the fact that further strengthening of producer organizations, building futures markets and increasing the availability of market information can contribute to reduce risk.

GOHIN – ZHENG (2020) argue that the prominence of futures markets (with low transaction costs) would greatly improve the well-being of European producers who are fundamentally at risk, as the distribution of risk could be improved. The simulations also emphasized the need to develop risk-based markets as opposed to systems based on intervention price levels.

In the case of Hungarian producers, effective commodity market risk management would be a significant step forward, but the benefits offered by the commodity market can be exploited without direct use of stock exchange. Available, transparent market information conveys a tremendous amount of information about the international and regional market situation. Proper interpretation of these informations can already help stakeholders shape their visions for the future.

At the hearing of the European Parliament's Committee on Agriculture and Rural Development (AGRI) on 23 February 2016 on measures to reduce price volatility, the Commission did not consider price volatility per se, but price volatility, the co-movement of raw materials and unpredictable future prices as the most worrying issues. Although price volatility remains a significant problem in agriculture, the Commission remarked that price volatility in the fertilizer and energy sectors was higher. In addition, compared to the US, producers' incomes in the EU were less volatile and did not fall to such an extent. The Commission concluded the focus should not be on price volatility but on income volatility primarily[4] (EUROPEAN PARLIAMENT, 2016).

Scientific publications, however, have been constantly analyzing price volatility. Because income data are available on an annual basis, mostly regionally, while price data are often available on a daily or more frequent basis. Price fluctuations sooner or later cause income fluctuations. Stabilizing producer income should be a fundamental aim, but I believe that further analysis of price volatility should be emphasized to understand the interaction between markets. Higher frequency data convey more information, which combined with an analysis of the income situation can lead to orders of magnitude more effective risk-taking. A further reason for the analysis of price volatility is the role of certain factors cannot be analyzed on an annual basis (e.g., high-frequency financial market interactions).

A risk management system will only be effective if farm financial situations are sound. Even the best risk management system cannot keep a loss-making stakeholder alive (SZENDERAK et al., 2019). The financial strength and resilience of farms vary from farm to farm and from Member State to Member State, although most EU farms may be able to survive a temporary loss of income of around 30% if they have flexible conditions (eg if

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[4] „The Commission' conclusion was that the EU should not focus on price volatility, but rather **address income volatility as a priority"** European Parliament 2016. Price volatility in agricultural markets *Risk management and other tools.* Brussels: European Parliament..

they can sell their liquid assets). (EUROPEAN COMMISSION, 2017b). It is necessary to take local conditions into account when developing risk management tools. This was confirmed by ASSEFA et al. (2017), where they examined different European countries and found that risk management strategies varied greatly depending on the country and the type of product. A solution could include the index-based approach presented in the dissertation, where risk periods can be determined on the basis of historical periods and / or forecasts.

4. NEW AND NOVEL RESULTS OF THE DISSERTATION

New and novel research results can be divided based on the secondary and primary research. In the course of the secondary research, **I would like to highlight the following novel results:**

a) **I have collected and systematized the most important factors influencing (horizontal) price setting.** I have presented the most significant empirical results related to price volatility and its spillover effects after 2010. The results demonstrate that price setting and spillover effects were the results of a highly complex network of international trade, energy market, competition between raw materials, financial market, exchange rate effects, stockpiling policies and global climate and weather change was also involved. After 2010, the surplus demand of the biofuel industry and the shocks caused by changing weather played a markedly great role. The results of the international and domestic literature confirmed that the effect of the listed factors was significant, but the strength of the effect varied depending on the analyzed period and locality.

b) **I presented the main characteristics of the production, processing and trade of raw materials in Hungary from the point of view of (vertical) pricing, with special regard to the effects of concentration.** The results confirm there is a high market concentration in the domestic food economy, which is increasing from the production of raw materials to retail. Vertical pricing is demand-driven and the bargaining position of retail is extremely strong. Agricultural production will be held back by competitive disadvantages. For low value-added raw material production, only a reduction in production costs can provide a competitive advantage, as value-added growth is not possible and the market purchase price is determined by processing and trade. Agriculture is also tied in terms of production and response, so unexpected weather shocks can have a critical impact on profitability. I briefly outlined the operation of the EU and Hungarian agricultural risk management system and its possible directions for further development. The agricultural risk management system is mainly aimed at mitigating the effects of supply shocks and, at the same time, improving the stability of the income situation. This mainly means drought and ice damage mitigation and the reduction of plant and animal health problems. The Hungarian policy mainly follows the recommendations and practices of the EU policy, taking the Hungary specifics into account. Most policies rely on some form of membership contribution, which provides a source of funding (with a government supplement) in case of certain regions or sectors are affected by an adverse risk event. The agricultural risk management system does not yet make use of the opportunities offered by the Income Stabilization Instrument and no area or instrument that focuses on price volatility and its spillover effects directly. In the Hungarian practice, the utilization of the commodity futures markets was extremely moderate, although this was typical for the whole EU.

The primary research sought answers to the following questions:

- **Does the volatility spillover effect between commodity markets change over time?**

The results supported that the spillover effects of price volatility changed over time. Its strength also depended to a large extent on the stability of the market and typically strengthened during market turmoil. The results highlighted that the conclusions drawn from constant parameter modeling may not always be valid, so it is worth focusing on time-varying parameter modeling in the future. To this end, the room for policy adjustments needs to be expanded accordingly. In the case of time-varying effects, not only was there a lack of stability but in almost all cases the markets did not have a defined transmitter or receiver role. Depending on the period, price fluctuations could have a spillover effect on receivers and transmitters. I have also detected a bidirectional relationship between commodity markets and crude oil prices, which result was consistent with the latest literature findings. The results of the dissertation also supported the view that commodity market interactions were much more complex than previously assumed.

- **Which factors can contribute to the time-varying volatility spillovers?**

According to the results of the primary research, the spillover effect of price volatility intensified during the market turmoil, so it can be assumed that the competitive effects between raw materials played a primary role. Also, spillover effects (as well as price movements) were mainly of fundamental origin, while energy and financial market effects were not significant in the long run. Nevertheless, they could have had a serious impact in the short term. It is important to note that real causal effects could not be detected by traditional econometric methods, so the calculation of the DY index should be limited to the most probable explanations. To get a more comprehensive picture, I processed in detail the commodity market events from 2005 (beginning of the sample). The dynamics changing over time also varied between raw materials, depending largely on its market position, end-use trends and the current market situation of substitute raw materials.

- **What are the risks of the changing volatility spillover effect and what tools can be effective in mitigating the risk?**

Research has revealed that price competition generates uncertainties in the short term as well, without a comprehensive tool in Hungary to deal with. It should be added that these tools were available in the EU, although their utilization was still low as well. In my opinion, the most significant effect was the increase in market uncertainty, thus bringing the short-term approach to the fore and declining long-term investments. This comes with a decline in producer efficiency, which should remain a priority in improving profitability. In reviewing agricultural risk management tools, it was explicit that mitigating supply side shocks were central to the current system, as these types of shocks had the greatest impact on producer income. The risk could be mitigated through methodological and sectoral tools. During the methodological aspects, I covered data collection, data quality and model use, while from the sectoral point of view I consider the development of innovative risk management tools to be important.

To the best of my knowledge, I used the DY spillover index for the first time to measure the volatility spillover effect between Hungarian and international commodity volatility. The extremely limited availability of data in Hungary and the low liquidity of the BSE futures market caused difficulties during the calculations. It would be extremely beneficial to expand the scope and frequency of data collection, as the index is extremely flexible, so interactions could be measured with other markets as well (for example with the financial market).

5. THE PRACTICAL APPLICABILITY OF THE RESULTS

The changing risk effects over time indicated that, depending on the periods, the interconnection of markets was stronger. During these periods, agricultural policy must take into account that the usual interactions may be overturned and new factors may shape the market. An efficient response requires a dynamic agricultural policy capable of rapid decision-making. As price volatility or its spillover effects can contribute to a decline in long-term investment, it may be important to develop appropriate long-term constructions. This would also lead to increased competitiveness, which would mitigate the negative effects of price volatility in the long run.

The path of the index showed that the volatility pass-through effects were mainly influenced by changes in fundamentals (demand and supply, especially changes in foreign trade). The situation of the markets thus changed depending on how the global and local market equilibrium developed. Contrary to the “traditional” view, markets did not have a defined role, they could be both net volatility spill-over transmitters and receivers to other countries. Nevertheless, there were dominant markets. However, the analysis of the literature also showed that the role of Europe and the Black Sea countries in formatting grain market prices had become increasingly important. This indicates that more attention needs to be paid to these areas in the case of Hungary as well.

Exchange risk management tools provide an effective way for market participants to hedge future risk arising from price changes. As stock exchange risk management tools were not widespread in Hungary, and their increased utilization is not expected in the future, it is necessary to develop innovative agricultural risk management tools. The agricultural risk management system is rightly aimed primarily at dealing with exogenous supply disturbances (like crop losses due to drought or other weather factors). However, it may be worth considering other factors, as the development of the index also suggested the emergence of new factors in certain periods. Delivery contracts with various pre-fixed parameters (e.g., buying at a pre-determined price with specified quality parameters) were common. Expanding and revising these could increase the participation of industry in such contracts. It also improves the predictability of revenues in the long run, thus reducing the proportion of adverse economic decisions due to risk. This, in turn, requires that the contract be mutually beneficial and that contractual discipline not be relaxed when more favorable options are realized. This area could be a possible future research direction.

Increasing sectoral cooperation can reduce the risk of price volatility. If a producer organization follows market prices, it has a very modest chance of achieving price stability. This could be improved with a retail food chain owned by the organization. At least a considerably closer link along the production, processing and distribution chain would be necessary. Many Hungarian retail chains have developed supplier programs, but their primary goal remained to satisfy consumer demand and maximize profits. In the event of market crises, the retail chain can easily replace the suppliers, so cooperation does not necessarily solve the problem of the production and processing phases. In the absence of certain risk management tools (or with their low utilization), price fluctuations can only be hedged with low production costs and increased competitiveness.

Of the similar, time-varying indices, the version presented in the dissertation is the most frequent and flexible, while easy to expand from a methodological point of view. This index (or similarly flexible indices) could be the basis for a measure of risk that, by constantly reassessing, would give industry participants an accurate and timely picture of current market interactions. Price monitoring and recording systems already exist, but their existence was mostly only aimed at increasing transparency. Effective analysis requires the collection of high-frequency data (especially daily data), making it available, and ensuring that this data is consistent with the data already available.

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Scientific journal in a foreign language

1. Fenyves, V. – Pető V. – **Szenderák, J.** – Harangi-Rákos, M. (2020): The capital structure of agricultural enterprises in the Visegrad countries. AGRICULTURAL ECONOMICS-ZEMEDELSKA EKONOMIKA 66 : 4 pp. 160-167. , 8 p. (2020) **IF: 1,106 (2019, Q1 – Q2)**

   Független idéző: 3, Függő idéző: 0, Nem vizsgált idéző: 0, Összes idéző: 3

2. Fróna, D. – **Szenderák, J.** – Harangi-Rákos, M. (2019): The Challenge of Feeding the World. SUSTAINABILITY 11 : 20 p. 5816 Paper: 5816, 17 p. (2019) **IF: 2,576 (2019, Q2)**

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3. **Szenderák, J.** –Popp, J. – Harangi-Rákos, M. (2019): Price and Volatility Spillovers of the Producer Price of Milk between some EU Member States. GERMAN JOURNAL OF AGRICULTURAL ECONOMICS 68 : 2 pp. 61-76. , 16 p. (2019) **IF: 0.5 (2019, Q3)**

   Független idéző: 0, Függő idéző: 0, Nem vizsgált idéző: 0, Összes idéző: 0

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5. Marczin T. – Nagy L. – **Szenderák J.** – Balogh P. (2020): Árelemzés a magyarországi sertésintegrációban. GAZDÁLKODÁS, 2. sz. 64. évf., pp. 117-133.
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Candidate: János Szenderák
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List of publications related to the dissertation

Articles, studies (9)

1. Marczin, T., Nagy, L., **Szenderák, J.**, Balogh, P.: Árelemzés a magyarországi sertésintegrációban. *Gazdálkodás. 64* (2), 117-132, 2020. ISSN: 0046-5518.

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