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SHOCK PROPAGATION MECHANISMS WITHIN INTERSECTORAL NETWORKS OF CENTRAL AND EAST EUROPEAN COUNTRIES

Master's Thesis

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Abstract

This paper investigates the production relations between economic sectors within seven transition countries – the Visegrád Four and the Baltic States. The relations can be embodied in country-specific square Input-Output matrices, which can be further illustrated as networks of vertices (sectors) and edges (transactions between them). The paper discusses the formulation and distinctive features of such networks. The main objective of the empirical part is to assess the networks' properties or, more precisely, their asymmetries from the perspective of the emerging literature of idiosyncratic shock propagation. In sum, 14 country matrices are analysed, constituting jointly for over 50 000 intersectoral transactions in 2015. The findings are as follows. The intersectoral networks of the analysed CEE economies are surprisingly divergent, with distinctive value chain shapes and different service-related or industry sectors acting as the central hubs. Meanwhile, the advanced EU economies present a much more homogeneous picture of services-dominated network structures. The shock propagation mechanisms, especially indirect cascade effects, may affect aggregate output volatility in all analysed countries. However, some transition economies seem to be more resilient to such cause of production fluctuations (Estonia, Czech Republic), whereas two other countries' intersectoral networks structures are particularly vulnerable (Latvia, Hungary). The paper contribution is proposing a new, comparative perspective on the outlook of the former Soviet Union economies in an early attempt to incorporate microeconomic shocks transmission study field to transition countries literature.

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Introduction

In 2020 the world was struck by a second once-in-a-lifetime global crisis within 20 years. The governments faced an extremely difficult trade-off deciding upon shutting down the whole sectors of the economy in order to save lives. The compromise had to be made quickly and under immense uncertainty, not only because of the lack of knowledge about the spreading virus, but also unforeseen implications for the whole economy. Up until recently, macroeconomic literature would consider this occurrence as an aggregate shock (e.g. Sims 1980; Kydland & Prescott 1982; Friedman 1995).

However, developments in the research areas related to IT and computational natural sciences have led to a new way of conducting economic analysis, aiming to show how a shock to one industry can propagate through an interconnected network of sectors to affect the whole economy. This is in contrast to a classic assumption of *diversification argument* (Lucas 1995), which suggests that micro shocks do not affect aggregate output, because they decay rapidly following the Central Limit Theorem. However, a growing literature shows that an uneven importance of relations between sectors can create mechanisms, which pass idiosyncratic shocks further in the network through first-order connections and indirect cascade effects (Gabaix 2011, Acemoglu et al. 2012, Carvalho 2014, Carvalho & Tahbaz-Salehi 2019).

In 2021 there was a shortage of supply from the semiconductor sector in Japan due to a plant fire. At the same time, drought in Taiwan[1] and global lockdowns limited import possibilities. Microelectronics industry faced disruptions and was not able to produce chips, used further down the supply chain by car manufacturers and by the consumer electronics sector. As a result, some flag models of major car companies did not premiere on time and Sony was not able to meet the demand for their new gaming console, which caused wide dissatisfaction among their customers (see e.g. The Economist 2021[2]; Wall Street Journal 2021[3]). The 2008 financial crisis could also be evaluated in terms of shock propagation between sectors, amplifying the volatility. It can be argued, that the transmission of shock, originating from the Tallinn house prices bubble, between the real estate sector and the financial services sector contributed strongly to the exceptional output volatility in Estonia at the end of 2008 (Brixiova, Vartia & Worgotter 2010, Cocconcelli & Medda 2013). The natural gas shortage in

[1] Chipmaking is a very water-intensive process.

[2] https://www.economist.com/the-economist-explains/2021/02/25/why-is-there-a-shortage-of-semiconductors

[3] https://www.wsj.com/articles/why-the-chip-shortage-is-so-hard-to-overcome-11618844905

Slovakia in January 2009, which was a result of unsuccessful negotiation between Ukrainian and Russian energy conglomerate, propagated rapidly to the manufacturing sector and caused a sizable slump in total production (Radvansky & Panikova 2012; Fasungova & Radvansky 2014). The disturbance in a gas energy sector could have similar impact on the other eastern EU members as well (Richter & Holz 2015).

The emerging field of intersectoral network studies can offer new tools to understand shocks, which strike particular elements of the economy, and their impact on the aggregate level. This paper aims to investigate the network properties of seven Central and East European Countries' (CEECs) economies and employ the methodological framework proposed by Acemoglu et al. (2012) to assess the risk of propagation of idiosyncratic shocks which may result in aggregate output fluctuations. By identifying distinctive features of the input-output relations in the countries, it is possible to make predictions about shock propagation channels and the identity of responsible central hubs. Subsequently, the outdegree structure is surveyed to quantify the extent of idiosyncratic shock sensitivity of a country. Furthermore, the paper aims to compare the results against other, advanced EU member states. The main contribution of the paper is introduction of a new perspective to the comparative studies of transitional economies. Comprehensive investigation of intersectoral networks of those countries allows to better understand their position compared to the developed neighbours and examine the catching-up process in the context of value-chains architecture and aggregate volatility. The findings are quite surprising. In every country cascade (indirect) transmission mechanisms are more important, however CEECs display very heterogeneous level of shock propagation tendency, with Estonia and Czech Republic being one of the most resilient countries in the EU, whereas Hungary and Latvia are the most vulnerable. Advanced EU countries seem more homogeneous, with network structures heavily favouring services-related sectors in the central positions. In transition countries, the structures of intersectoral networks are diverse, with some distinctive attributes in every country, and most central sectors are evenly distributed between services and industry.

The paper is organised as follows. Chapter one starts with the topic-focused literature review from the related study fields: business cycles, multisectoral economy models, and the young field of research on networked economies and idiosyncratic shocks. The following subsection describes the data format (Input-Output tables) and introduces all the necessary transformations to it. The second chapter provides an introduction to the forming process of intersectoral relations in investigated countries. It aims to give an overview of the importance of privatisation process, external macroeconomic environment and foreign capital inflows to the current state of networks. The next chapter proceeds to analyse the multisectoral networks of CEECs - the V4 (Czech Republic, Hungary, Poland, Slovakia) and the Baltic States (Estonia, Latvia, Lithuania). Starting with a brief review of related, country-specific literature, each country network is consecutively investigated in general and detailed lenses, paying attention to distinctive structures able to propagate shocks. The following sections aim to extract more information from the Input-Output matrices and compare the findings between countries. The last chapter introduces the multisectoral microeconomic model and shock transmission mechanism, following Acemoglu et al.'s (2012) framework. Finally, the results of the empirical investigation are presented and, in the end, the conclusions are drawn.

1. Economy as a Network

1.1. Literature review

Robert Lucas presented his influential ideas about business cycles in 1976. He proposed a narrative explaining repetitive fluctuations of aggregate variables, such as employment or output. Lucas (1976, 1995) goes back to Hayek's (1934) considerations in an attempt to bring the puzzle back to the centre of economists' attention after being somewhat disregarded during the Keynesian revolution.

For decades Lucas's *diversification argument*, resonating well along with portfolio diversification studies (Markowitz 1959), neglected idiosyncratic shocks. According to the argument, the aggregate variables concentrate on the mean very quickly in a highly disaggregated economy. Specifically, the volatility should vanish in the rate of $\sqrt{n}$, where n is a number of sectors (or firms). However, a new approach to aggregate production volatility in the economy emerges. Taking into consideration the interrelations of sectors allowed economic analysis to reach beyond the widespread horizontal model of the economy assumption (Figure 1a) and cast some doubts on the argument[4].

[4] Sectoral interdependencies where argued for also prior to Lucas's works, e.g. Von Neumann (1945)

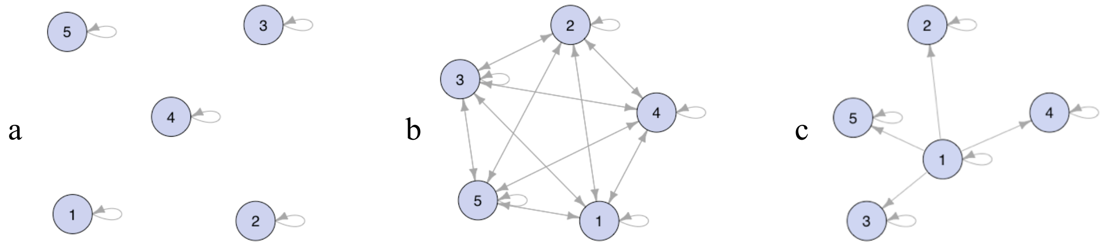

Figure 1. Three model economies: Horizontal, Full network and Star-like structure.
Source: Own illustration using the *igraph* R package

Figure 1 illustrates three model economies consisting of five sectors (vertices) each. Example 1a depicts a network without any input-output relations (edges) between industries. Each sector is self-sufficient in terms of production. Idiosyncratic shocks do not propagate to other sectors, and aggregate volatility decays according to the *diversification argument.* Figure 1b displays a network where each sector uses the same input share from every other sector in their production technology. The production relations are symmetric, thus not-correlated microeconomic shocks are expected to cancel out along with the diversification argument, meaning the rate of decay is determined by the disaggregation level (square root relationship). Therefore, a complete network is another instance where idiosyncratic shocks to sectors do not contribute strongly to aggregate fluctuations. Example 1c, however, has a less symmetric structure. Sector 1 plays important role of a sole input provider to four other sectors. A shock to this industry propagates through direct connections to the whole economy, which entirely relies on its output. A start-like structure is the most vulnerable type of economy regarding the influence of an idiosyncratic shock on aggregate production (Carvalho 2008).

The roots of alternative approaches to fluctuating business cycles were established by Long and Plosser (1983), followed by Horvath (1998, 2000). Carvalho and Gabaix (2013) surveyed broad literature body and empirical evidence to investigate extensively the hypothesis that, in fact, the microeconomic shocks are the primary source of aggregate volatility. They found that fundamental volatility (derived from traceable, idiosyncratic shocks) has high explanatory power of output volatility, putting aside the influence of monetary shocks, effects of policy changes, taxes etc. Additionally, when considering financial frictions, volatility poses welfare losses, therefore microeconomic composition of sectors should be systematically focused.

The authors examining economic network interrelations took two closely related paths to come up with complementary results. Some investigated network properties of firms, others – industries. Gabaix (2011) introduces the notion of *granularity* as the key feature characterising firm size distribution contributing significantly to aggregate volatility. In particular, the heavy tail of empirical distribution indicates that the *diversification argument* fails. This is because there are very few exceptionally big firms in the sample, capable of transmitting a micro shock to a significant number of other firms before it averages out. Gabaix and Ibragimov (2011) further contributed to tail analysis in context of its' granular properties by proposing modified log rank-log regression tool for estimation to account for downward bias of standard OLS in small samples[5]. Di Giovanni, Levchenko and Mejean (2014) explore a new database of French firms' transactions to look for evidence of individual contribution towards aggregate sales volatility. The authors confirm that input-output linkages of firms and fat-tailed firm size distribution are partly responsible for such fluctuations. Eratalay and Vladimirov (2020) employed a network analysis to assess interconnectedness of firms listed on the Moscow Stock Exchange and found evidence of increased vulnerability of the network structure after the financial crisis. In a new, fascinating paper by Carvalho et al. (2021), the impact of earthquake in eastern Japan on a supply network of almost a million firms is surveyed. The disruptions in input-output relations were propagated through direct and indirect connections and resulted in estimated 0,47 percentage point fall of Japanese real GDP next year after the catastrophe.

Inter-industry financial flows, based on input-output tables, have been analysed not only by economists. McNerney, Fath and Silverberg (2013) focus on networks' topology and community structure, in a sample of 45 countries and industry disaggregation level varying between 32 to 41, to identify cross-country persistent sectoral clusters, varying in several dimension (likelihood of export, revenue from final demand etc.). The article gives a fresh perspective on intersectoral networks and adds additional evidence of industrial networks' internal heterogeneity. Another contribution from computational natural-sciences field comes from Blochl et al. (2011). The authors proposed a dedicated algorithm to measure centrality scores of vertices within Input-Output networks and tested them empirically on a sample of 37 countries' economies consisting of 47 industries. Interestingly, CEE countries included in the

[5] This estimation approach is used in the 3rd chapter of the essay, following Gabaix (2011) and Acemoglu et al. (2012) methodology.

analysis seem to have some common features in terms of centrality structure of their networks, but are not that closely related to other European countries, especially the Nordics.

The most important article from the perspective of this essay (and arguably, the new field of micro shock transmission research) is Acemoglu et al. (2012). The authors arrive with systematic mathematical framework to formally capture effects which a single sector can have on aggregate fluctuations in the networked economy. They distinguish between the immediate mechanism, originating from direct input-output relations between sectors and the cascade mechanism, which arise from a key intermediary role of a sector within a value chain. Those mechanisms can be measured by using country-specific Input-Output Product-by-Product Total Direct Requirements matrix to calculate first- and second-order outdegrees of each sector. Essentially, it is shown that in multisectoral model with shocks, an equilibrium depends from an *influence vector*, which captures the distribution of aforementioned outdegrees in the economy. This is further explained in Chapter 3 of this essay. Moreover, the authors apply this framework to the US economy input-output structure and show, that it is vulnerable from both of the idiosyncratic shock transmission mechanisms, with indirect effects playing more important role[6].

Carvalho (2014) establishes baseline facts on recent developments and describes some fundamentals of intersectoral network structure analysis from the perspective of shock propagation. Carvalho with Tahbaz-Salehi (2019) provide the most exhaustive survey of all related research avenues available to this date.

1.2. Input-Output tables

The starting point for any network analysis is a database in the form of an *adjacency matrix*, capturing relationships between vertices (Newman 2004). In the emerging research area of economic networks and aggregate volatility, the role of the adjacency matrix is taken by Input-Output tables, which illustrate financial transaction between sectors (or firms). The father to Input-Output approach in Wassily Leontief, award the Sveriges Riksbank Prize in Economic Sciences in 1973 for his contribution to intersectoral analysis (Dietzenbacher, Lahr 2004). He realised that even though the ties between industries are invisible, they are very real "when sudden shutdown of the Pennsylvania coal mines paralyzes the textile mills in New England […]" (Leontief 1941).

[6] This was followed by related literature suggesting that the indirect effect may dominate in empirical investigations, see Acemoglu, Akcigit & Kerr (2016).

Sectoral Input-Output (IO) tables capture how much input does one sector use from every other sector in order to produce goods. For example, how much of steel, microchips, textile, energy… etc. is needed for the total output of a car industry. The tables are usually published by countries' statistics offices (most of the EU members) or other adequate public institutions (National Accounts Institute for Belgium, Bureau of Economic Analysis in the USA) (Eurostat 2020). IO tables are derived by transforming Supply and Use Tables, which are compiled from multiple data sources, including businesses' and households' surveys and data from administrative sources, trade or companies. The countries' tables are very diverse in many dimensions. They may indicate product-by-product or industry-by-industry transactions, use different base assumptions (namely product- or industry-technology assumption[7]) and display different disaggregation level (Eurostat 2008). For example, data for Estonia is originally published by Statistics Estonia in five-year intervals, 1080 days after the reference year (meaning last available table is for 2015). The desegregation level of Estonian IO tables is 64 industries[8].

To sum up, using data from original providers for comparative analysis is not straightforward (and would add months of work to the study). Fortunately, there are three sources which provide more homogenous data for multiple European countries on the following disaggregation levels:

- OECD – 36 sectors
- World Input Output Database – 52 sectors
- Eurostat – 64 sectors

This analysis is carried out on product-by-product data from Eurostat, given it offers the highest level of disaggregation, which should allow to better capture the tails of degrees distribution behaviour. Nevertheless, the database has been carefully scrutinised for any possible discrepancies with the national suppliers of IO data (see Appendix Table 2A for all introduced corrections). The available tables do not resemble the Input-Output matrix which could be used as adjacency matrix and would allow to capture outdegrees structures. Some transformations need to be performed before advancing with the analysis. The starting point are tables with yearly total (domestic + import) transactions between all sectors at basic prices

[7] Product technology assumption implies that each product is produced in one way, regardless of the output industry, whereas industry technology assumption means that each industry has its' own specificity of production (regardless of the product) (UN, 2018).

[8] Disaggregation in the other EU members for comparison: France 38; Spain 63; Belgium, Lithuania, Latvia 64; Germany 73; Austria 74; Poland 77; Czech Rep. 88. BEA publishes detailed IO tables for 470 sectors in the US.

in national currency. Tables are not square and account for many additional statistics, such as change in inventories, wages or taxes less subsidies.

To object of this analysis is a direct requirements' $n \times n$ matrix – W_n. Each element of the matrix, w_{ij}, shows how much of input from sector *j* is required to obtain a unit of sector's *i* product. In other words, this is a share of sector *j* input in the production technology of sector *i*. This implies that the sum of each i^{th} row is equal to one and a sum of a column is an outdegree of a sector, which's meaning will be further explained in the next chapters. To obtain the W matrix, the calculation was performed:

$$W_n = \begin{bmatrix} w_{11} & \cdots & w_{1n} \\ \vdots & \ddots & \vdots \\ w_{n1} & \cdots & w_{nn} \end{bmatrix} = E \cdot I \times \overrightarrow{(TOT)}^{-1} \quad (1)$$

where

E – Eurostat Input-Output table of monetary transactions between sectors

I – Identity matrix

$\overrightarrow{(TOT)}^{-1}$ – Inverse of a total output vector

Some countries, including USA, publish the Input-Output data in Total Requirements format. This captures all direct and indirect requirements of an industry to produce and means that the transformation process is slightly different. The matrix illustrating total requirements of sectors is known as Leontief Inverse, denoted as $(I - W)^{-1}$ (Leontief 1986).

2. The Context of the Shaping Process of CEECs' Multisectoral Economies

2.1. Transition and EU accession

The architecture of intersectoral networks of Central and Eastern European Countries' economies is a result of market forces impacting the existing structure of value chains, inherited from the Soviet Union, in a country-specific institutional setting. After the fall of the Berlin wall, rapid connection to global financial systems and liberated trade helped to reshape the economies. The remaining, post-soviet value chains have been incorporated along the progression of privatisation process, while inflow of Foreign Direct Investments (FDIs) helped to facilitate the transformation (Johnson, 2006). FDIs allowed to bridge the *idea* and *object* gaps highlighted by Romer (1993) and newly established linkages within Global Value Chains helped to facilitate knowledge and technology spillovers (Holland et al. 2000).

The adopted transition strategies differed among Eastern bloc countries. Centrally and northern located European countries followed a dynamic path of quick privatisation and intensive FDI inducement in line with the *Washington Consensus* (Williamson 1990), whereas southern countries adopted more gradual approach. Furthermore, former Soviet Union (FSU) states endorsed Rodrik's (2006) augmentation of the Consensus, which targeted corruption, construction of social safety nets or limitations to the spread of inherited informal-practices[9], in a different pace. Ultimately, the industrial policy of the *post-Washington* generation of regulations defined the intersectoral network structure, as it focuses on scaling up the success stories by promoting selected linkages and sectors to facilitate their interconnectedness in the global value chains (Radosevic 2009). It should be also noted, that the starting point of a transition process for investigated countries is not exactly the same. While the V4 countries regain independence at the end of 1989, Lithuania followed in March 1990 and Estonia with Latvia separated completely from the Soviet Union in the third quarter of 1991. Although the reforming policies in Baltic States were comparably intensive to the V4 (especially in Estonia), this almost two-year lag should be taken into the account (Aslund et al. 1996).

Some theoretical models argue for 'the faster the better' restructuration of transition economies after taking into the account the potential implication for unemployment rates (see Blanchard 1997; Aghion & Blanchard 1998). However, not only the well-suited tempo of privatisation is determinant of the transition country output. Kalotay and Hunya (2000) showed, that in Poland and Hungary the production grew faster than in other CEECs partly because of a significant proportion of foreign-owned companies included in the process[10]. On the opposite, Kattel, Reinert and Suurna (2009) point to the destruction of Soviet Union inherited production chains due to foreign investors being interested only in a particular part of a chain. This process, apart from resulting in unemployment due to disintegration of existing production chains, contributed to a regress in terms of skill- and technology-intensity of industrial structure.

The market liberalisation settings, such as comprehensive competition policy, further allowed to facilitate the privatisation process. Drahokoupil (2007) distinguishes competition

[9] Those were often difficult to distinguish from small-scale theft or cronyism and nepotism (Ledeneva 2018).

[10] This somewhat general statement should be revised along later *absorptive capacity* literature on positive inward FDI spillovers and ambiguous results of FDI impact on growth (see Iwasaki & Tokunaga (2014) for meta-analysis of the literature body in this matter)

states in V4 and the Baltic States, where the former used direct subsidies to attract strategic FDI while the latter countries concentrated on neoliberal reforms to establish macroeconomic stability and lure foreign capital. Still, it was partly up to multinational companies to adapt their acquisition strategies and models to the institutional settings of all of the FSU countries (Uhlenbruck & Castro 2000). Institutions determine transaction costs for entering multinational enterprises and could influence the mode and volume of foreign investments (Meyer 2001; Bevan, Estrin & Meyer 2004). Another interesting perspective on the impact of different type of institutional setting on privatisation is presented by Bjornskov and Potrafke (2011), who investigated the role of government ideological position in transition countries and concluded that right-wing leaning decisionmakers where associated with privatisation focus on smaller and medium-size industries.

The development of Visegrád 4 and Baltic economies was further stimulated by the accession to the European Union in 2004. Geometric centre of manufacturing activities in the EU shifted to the east[11]. Common agricultural policy and the inflow of structural funds had a big impact on the intersectoral structure in New Member States, especially on changing a position of former core sectors (like agriculture, forestry or food-related services) and development of new key industries (e.g. construction) (Gurgul, Lach 2015). Nevertheless, countries were impacted differently by funds inflow under EU Cohesion Policy. Dobrinsky and Havlik (2014) reveals heterogeneous convergence paths within New Members States after EU accession. Horridge and Rokicki (2018) present a comprehensive evidence from a series of dynamic general equilibrium models, proving that although each Visegrád country grew faster because of the accession, the impact for initially less developed regions (in terms of GDP *per capita*) is much greater. This also implies significant differences in impact of Cohesion Policy between those countries[12]. Some policies, such as *Smart Specialisations*, directly fostered further divergence among CEECs (Dyba et al. 2018). Finally, the EU-related industrial networks reshaping and alignment forces should not be treated as exogenous. Radosevic (2003) points out that although the demand from the European Union is a powerful attractor for emerging industrial networks, the policy implementation capability of CEECs is defining to the robustness of emerging structures. Harding and Javorcik (2012) measured the effectiveness of such active attitude, which involve targeting the FDI inflows in selected sectors in

[11] Literally, also within old EU member states boarders, see Brulhart, Crozet & Koenig (2004).

[12] According to the study, poorer Polish regions benefited the most, whereas Prague and Bratislava – the least (*ibid.*).

developing economies and found that these efforts on average double the volume of foreign investments in those industries.

To sum up, the dynamics of transition in CEECs are prominently disparate. It can be argued that a somewhat chaotic and rapid process of integration to the global markets as well as de- and re-industrialisation in CEE might have in fact helped to establish new, local value chains (Jaklic, Raskovic & Schuh 2018). Nevertheless, it is the country-specific institutional environment of the FSU states that has had a profound role in the catch-up process. It influenced the outlooks of the CEE countries' economies, especially on the early stages of the transformation (Meyer, Peng 2016). This hints that treating those countries in the same category, or even as similar beings, may lead to substantial and consequential oversimplification (Kostova, Hult 2016).

2.2. Foreign Direct Investments perspective

FDIs can contribute to the development of countries' intersectoral networks through a variety of channels. For instance, a horizontal knowledge spillover can assist the multisectoral structure evolution on a micro level by a simple mechanism: a proportion of a former transnational companies' employees will start their own business in the same field, relying on the knowledge and experience gained in a foreign subsidiary (Moran 2014). This occurrence was investigated by Javorcik and Spatareanu (2005) within managers in Czech Republic and Latvia, who claim to apply e.g. marketing and sales techniques learned from foreign directors. In terms of vertical spillovers in Baltic States' economies, Javorcik (2004) found robust evidence of a production rise among Lithuanian suppliers when a downstream sector is more penetrated by foreign firms and capital. At the same time, 90% of multinationals' affiliates in Czech Republic used at least one domestic supplier (with median of such linkages equal to ten). Pavlinek, Domanski and Guzik (2009) conducted extensive analysis of automotive industry in Visegrád 4 countries to conclude that substantial inflow of FDI to particular sector in a less economically advanced country stimulates industrial restructuration and facilitates new upstream firms in a country network.

Therefore, the concept that '[…] *FDI may serve as a catalyst for upgrading the national production structure in an emerging economy'* (Javorcik, Lo Turco & Maggioni 2018) is what prompts to look into the FDI stock structure in investigated economies to better understand the origins of analyzed intersectoral networks. Especially in the light of suggestions, that the New Member States in particular were able to benefit from inward FDI in terms of structural changes (Kalotay 2010).

Poland attracted the most FDI among analysed countries in terms of a total inward stock at 235 billion USD. However, when comparing *per capita* values, which is more appropriate when considering the impact of such investments on the whole economy structure, another picture emerges. Figure 2 presents the inward FDI stock per capita in 2018 with a distinction between second and third generic sectoral categorization of investment destination. Estonia leads the chart with a total of 21131 USD *per capita*, 80 per cent of which could be accounted for services sector. Focusing on the stock distribution, it seems that the V4 countries attracted on average a bigger share of the manufacturing targeted FDIs than the Baltics. Poland leads this statistic with almost a third of the stock in the secondary sector, while in Latvia it is only 11,6%.

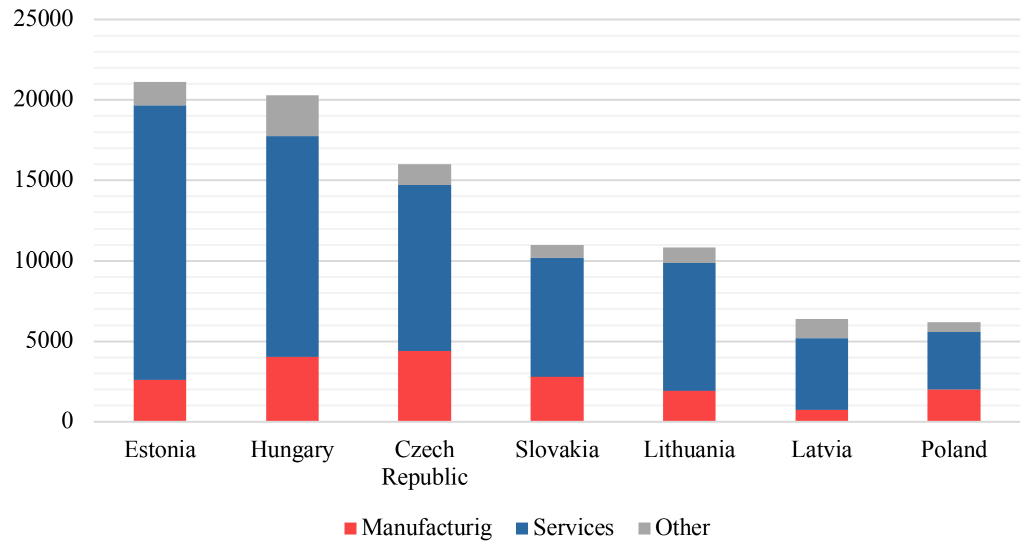

Figure 2. Total inward FDI stock in 2018, US Dollars *per capita*.
Note: Secondary and tertiary sector category correspondingly in red and blue. The grey category, *other*, includes primary sector, constriction, energy, water sectors and confidential values.
Source: OECD data, own calculations.

The proportion of manufacturing stock can be meaningful for intersectoral network development within countries. Narula and Bellak (2009) argue, that the potential to generate spillovers and positive externalities makes those FDIs of greater significance than any other. Additionally, they claim that development of services sector is somewhat secondary, as it stems from the demand of the industry for research and development, banking services or designing a product. Nevertheless, it is important to keep in mind that for industrial development based on foreign capital inflow, some preconditions are vital, such as sufficient absorptive capacity and complementary (as opposed to substitutive) character of relations between domestic and foreign value chains (Dunning and Narula 2005).

Table 1

Inward Foreign Direct Investments sectoral distributions in CEE countries in 2018

Estonia		Latvia	
Real estate activities	18,0%	Real estate activities	16,0%
Monetary intermediation	15,8%	Monetary intermediation	14,3%
Wholesale trade	8,3%	Wholesale trade	12,1%
Information and communication	5,0%	Transportation and storage	5,1%
Transportation and storage	4,4%	Private real estate activities	5,0%
Activities of holding companies	4,3%	Total primary sector	4,7%
Activities of head offices	4,1%	Construction	4,1%
Manufacture of textiles	3,5%	Manufacture of textiles	4,0%
Manufacture of food products	2,9%	Activities of holding companies	3,7%
Other	36,6%	Other	34,7%

Lithuania		Czech Republic	
Monetary intermediation	16,4%	Monetary intermediation	12,7%
Real estate activities	12,6%	Activities of holding companies	11,9%
Wholesale trade	7,3%	Real estate activities	8,3%
Information and communication	6,9%	Manufacture of motor vehicles,	7,7%
Activities of holding companies	6,8%	Manufacture of metal and machinery products	7,2%
Management consultancy activities	5,7%	Wholesale trade	5,4%
Manufacture of petroleum, chemicals	5,6%	Information and communication	5,3%
Retail	3,8%	Other manufacturing	5,0%
Insurance	3,6%	Activities of head offices	4,4%
Other	34,8%	Other	32,1%

Hungary		Poland	
Activities of holding companies	27,7%	Monetary intermediation	10,1%
Manufacture of motor vehicles	6,1%	Real estate activities	9,8%
Manufacture of petroleum, chemicals	5,4%	Wholesale trade	7,7%
Manufacture of metal and machinery products	5,0%	Manufacture of motor vehicles	6,5%

Real estate activities	4,6%	Manufacture of metal and machinery products	6,1%
Wholesale trade	3,5%	Retail	5,7%
Private real estate activities	3,0%	Manufacture of food products	5,7%
Administrative and support service activities	2,9%	Information and communication	5,5%
Information and communication	2,6%	Construction	5,5%
Other	39,2%	Other	37,4%

Slovakia	
Management consultancy activities	17,3%
Manufacture of metal and machinery products	12,0%
Real estate activities	10,6%
Wholesale trade	10,4%
Information and communication	9,8%
Transportation and storage	5,5%
Electricity, gas	5,0%
Manufacture of petroleum, chemicals	4,4%
Advertising and market research	4,1%
Other	20,8%

Note: Proportion of total inward FDI position in 2018 across the top ten sectors in each country.
Source: OECD data, own calculations.

Table 1 presents more precise overview of foreign investment sectoral destinations is CEECs. This is particularly relevant for understating the formulation of intersectoral architecture in those countries in perspective of agglomeration effects literature, which argues that establishing forward and backward linkages by foreign affiliates in certain sectors leads to self-propelling mechanism, where future FDIs are more likely to target same sectors (e.g. Campos & Kinoshita 2003; Lefilleur, Maurel 2009). Bijsterbosch and Kolasa (2010) employed a battery of quantitative tests to assess the influence of absorptive capacity of the FDI recipient industries on productivity in V4 countries, Baltics and Slovenia. Among other observations, they stressed the notable heterogeneity between those countries in aggregate output and inward FDI flows, especially on higher levels of sectoral disaggregation. This hints that such divergence may be also noticeable in the empirical investigation presented in the following chapters of this essay.

In most of the investigated countries, the biggest share of FDIs targeted the financial sector, with the exception of Estonia and Latvia, where real estate services dominated. Manufacturing investments in V4 countries were aimed primarily into the production of motor vehicles, other machinery and metal industry. Additionally, relatively big proportion of foreign financial flows accumulated in energy sector in Slovakia (over 5%) and the primary sector in Latvia (with significant advantage of forestry and agriculture over mining related sectors). Final noteworthy observation is a high position of the construction sector in two countries: Poland and Latvia.

Table 2

Inward Foreign Direct Investments sectoral distributions in the Baltic States in 2005 and 2018

	Estonia		Latvia		Lithuania	
	2005	*2018*	*2005*	*2018*	*2005*	*2018*
All FDI activities	11 192	25 096	4 906	17 473	8 450	19 418
Agriculture, forestry and fishing	66	523	77	662	58	339
Mining and quarrying	45	89	25	167	50	61
Manufacturing	1 673	3 197	578	2 039	3 187	3 408
Electricity, gas, steam and air conditioning supply	160	190	604	637	1 022	304
Water supply; sewerage	137	126	14	7	18	11
Construction	246	239	204	725	146	336
Wholesale and retail trade; repair of motor vehicles and motorcycles	989	2 910	633	2 781	901	2 325
Transportation and storage	324	1 099	303	892	119	460
Accommodation and food service activities	50	119	47	182	73	143
Information and communication	97	1 258	301	558	1 056	1 340
Financial and insurance activities	5 583	7 769	1 254	4 194	1 178	5 446
Real estate activities	1 545	4 518	329	2 788	300	2 442
Professional, scientific and technical activities	68	1 598	184	343	125	1 929
Administrative and support service activities	138	639	48	214	39	378

Note: Total inward FDI position in 2005 and 2018, absolute values, millions of US Dollars.
Source: OECD data, own illustration.

Last illustration (Table 2) gives perspective on a shifting aim of FDI in Baltic countries[13]. This may allow for better understanding of the dynamics of FDI inflows impact on multisectoral network shaping process. Havlik (2014) suggests that in fact more structural industry transformations can be observed in Baltics than Czech Republic, Slovakia or Slovenia. The author also points to a revival of manufacturing sectors after the crisis in the former countries. Another characteristic feature of Baltics' FDI is that closeness to technological frontier has a positive impact on productivity gains, which is in contrast to Central European countries, where the mechanism seems to be inverted (Bijsterbosch and Kolasa 2010).

The total stock of inward FDI doubled in Estonia and Lithuania and tripled in Latvia between 2005 and 2018. The biggest absolute differences account for real estate in Estonia and financial services in Latvia and Lithuania. In the latter country, the aforementioned change in inward FDI position is equal to + $4,26 billions, which the biggest amount in the sample. In the relative terms, the biggest change between pre-EU and pre-crisis FDI stock and most recent period concerns professional and scientific services. In Estonia and Lithuania, the amount of capital from abroad invested in those activities is now more than tenfold of what it was in 2005. Interestingly, this is not the case in Latvia, where the biggest relative rise (+760%) relates to the agriculture and forestry.

It is important to keep in mind that presented FDI statistics are most likely suffering from many imperfections, distorting the true state of foreign capital allocation in transition countries. Multinational companies employ Special Purpose Entities (SPEs) to engage in financial offshoring in order to avoid unfavourable regulations and taxes. This implies capital flowing through multiple financial hubs and so-called tax havens, having numerous negative effects on home and host countries and on the data quality as well (Raposo & Mourão 2013; Borga 2016). This can have a significant impact on the outlook illustrate above[14]: In 2017, almost 40% of inward FDI in Hungary originated in one of the financial offshoring hubs. Meanwhile, Hungary contributed to over $41 billions of phantom FDI in 2017 globally (meaning the country acts as a capital transit hub as well). This indicates that a considerable proportion of foreign investments is just 'passing by' the economy and a big chunk of

[13] Unfortunately, early data on V4 countries' FDI sectoral destinations is not available in the OECD database.

[14] Recently, a new OECD BMD4 database became available, allowing to track FDI for the ultimate investor country. The differences are surprisingly substantial. The new data seems to perform better in FDI related quantitative research (Ferto & Sass 2019), however it is not yet available within sectoral disaggregation statistics.

confidential values accounted for financial activities may not actually contribute in the same way to the position of financial sector in intersectoral network of Hungary.

Another practice responsible for blurring the overview of FDIs is round-tripping, which involves domestic company disguising as foreign in order to avoid taxes or receive other benefits aiming to attract investments from abroad (Aykut, Sanghi & Kosmidou 2017) According to aforementioned novel database, it is possible to estimate the extent of the practice. Czech Republic seems to be a global leader in such operations – over 14% of total inward FDI stock in 2017 actually originated in the country itself[15].

3. Intersectoral Network Structures in CEECs

3.1. Input-Output networks architecture

This section investigates network structures of the seven CEE countries' economies one-by-one, starting with the Baltic States, and following with the Visegrád Group. The analysis is conducted on the two different level of detail illustrations to present clearer perspective on all the meaningful features. The general outlook of interconnected sectors with high sensitivity to input-output relations allows to distinguish most central sectors. More specific picture of only the most important intersectoral directed relations helps to evaluate pivotal supply chains of the economies. For each country, the analysis starts with gathering the clues about network formulation process, which are scattered within broad, multidisciplinary literature body.

Estonia

For the smallest Baltic economy, the core of the transition and sectoral restructuration processes, after liberating the markets and prices, revolved around strategic FDIs inducement. According to former prime minister, in Estonia, the decision for proactive inducement of foreign capital parallel to close dialogue with trade unions accompanied by a strong turn towards free media and rule of law, placed the country on a quick path to growth and prosperity, leaving most of the transition economies behind in the 1990s (Laar 2008).

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[15] Additionally, round-tripping accounts for 8% of FDI in Estonia, over 4% in Poland and 2% in Lithuania. Interestingly given its offshoring results, Hungary is the least involved in round-tripping from all the countries with available data (<0,5%).

In opposite to (naturally) optimistic views of Mr. Laar, Vissak and Roolaht (2014) argue that FDIs might have had various negative effects on the Estonian economy. They point out to examples of tax avoidance by foreign owned companies and political pressure on home government through lobbying. More interestingly for the scope of this analysis, the authors suggest that FDIs contributed significantly to unequal development of the country, because of being primarily Tallinn focused. Additionally, almost half of the foreign investments are in the finance and transport services, making those sectors vulnerable from shocks originating abroad (see Kattel & Raudla 2013; Varblane 2017 for more about Estonia external vulnerability).

The literature on sectoral structure of Estonia is rather scarce compared to innovation- or FDI-related research. Some clues about the role of such network composition however can be extracted from this field of expertise as well. Analysing "industry bias" in R&D expenditure distribution across countries gives some perspective of how the sectoral structure affect innovation in CEE. Merikull, Eamets and Varblane (2012) find, that sectoral composition, despite being divergent, does not explain much of the differences between Western Europe and CEE in terms of creation of the knowledge base. Varblane, Mets and Ukrainski (2008) investigate the university-industry-government linkages to address problems of innovation policies in catching-up economies, which are neglecting low-tech sectors through over-focusing on high technology industry. The authors stressed the potential danger of creating a *dual economy,* where small high-tech sector would be isolated from the main structure with lower-level technology, lower productivity and low wages.

There is also a non-negligible body of literature focusing one distinctive sector or class of sectors is Estonia. Ukrainski and Varblane (2005) analyse innovation channels related to wood industry in Estonia and conclude with the guidelines for further evolution of those sectors, which include developing the value network with the government, especially in terms of high-end production. Hogselius (2002) describes the process of formulating Telecommunication sector in Estonia in historical and institutional perspectives. The author highlights the importance of establishing new linkages, allowing to connect value chain pieces inherited from Soviet Union on the one side with network operators and small, domestic software companies on the other. Additionally, the role of public procurement was crucial because it put pressure on the productivity with the additional demand and further boosted competitiveness. Ashyrov, Paas and Tverdostup (2018) conducted an input-output analysis of *blue industries* in Estonia and Finland. They come up with conclusions that sectors related to the marine activity are independent and have relatively weak backward linkages, therefore the *blue economy* should have little impact on the whole structure of the economy. The authors also point to less stability observed in Estonian sectors' roles over time. However, this analysis has a shortcoming of including almost a quarter of all sectors in the sample, which involves i.a. *Mining and quarrying*, *Motor vehicles* or *Construction*. Those broad-range sectors in sum capture a significant part of the economy not related to sea activities in any way and therefore make the cluster definition rather vague when looking at the relations in a whole intersectoral network of a country.

The most thorough analysis of Estonian sectoral structure and its' change was conducted by Paas and Sepp (2009). The starting point for the Estonian economy in the 1980s, according to the authors, was a "typical industrial country" influenced by local natural resources (namely oil shale). The transition process was driven by a rapid grow of wholesale and retail services along with introduction of modern banking and real estate services. They stress the importance of trade, FDI and real estate boom on shaping the new intersectoral structure. While assessing 2000s structural change, the authors note that CEECs still have a relatively big share of manufacturing industry compared to older EU members, despite slow decline in favour of services. On the path to convergence towards the structure typical for more developed countries, Estonia and other New Member States face the problem of simultaneous de-industrialisation and moving to high value-added sectors, while avoiding unnecessary damage. Finally, the authors conclude with a plea for the systemic path-dependency analysis to promote structural change in Estonia.

Overall, the literature body gives perspective on what forces helped to shape the intersectoral network of Estonia. It hints some expected differences between old and new EU member states but also points some distinctive features of Estonian sectors' relationships. The following analysis should shed some more light on the input-output network of this small open economy and on how likely it is to propagate shocks to a certain sector, causing the aggregate volatility.

Figure 3 presents a model of Estonian multisectoral, networked economy. In other words, this is the Input-Output matrix obtained according to calculation presented in Chapter 1, serving as adjacency matrix of a network, and subsequently visualised. Vertices represent individual sectors according to CPA disaggregation method followed by Eurostat (see Table 1A in the Appendix). Services-related sectors are marked with blue colour, all other sectors are red. Vertex darkness and size corresponds to eigen centrality score[16], which measures direct

[16] Eigen centrality is directly related to more comprehensive notion of Bonacich centrality, introduced as equation 4 further in this chapter. In particular, it assumes higher-order discounting factor (β) equal to one

and indirect interconnectedness of a sector based on eigenvector values of an Input-Output matrix. This is further explained in the subsection 2.4. and chapter 3, considering sectors with the highest centrality scores may act as idiosyncratic shock propagators to the whole economy. Edges between vertices illustrate transactions between sectors, i.e. the elements of an input-output matrix - w_{ij}. Only transaction greater than 1% of a total input are illustrated and edges representing value added of a sector to its' own production are omitted (no w_{ii} visualised). Furthermore, width of an edge represents importance of an input-output relationships for sectors. In Estonian case, the widest edge (located between sectors 42 and 43) represents the input of sector *Services auxiliary to financial services* to sector *Insurance, reinsurance and pension funding services*, which constitutes for 61% of the total input required by the latter sector.

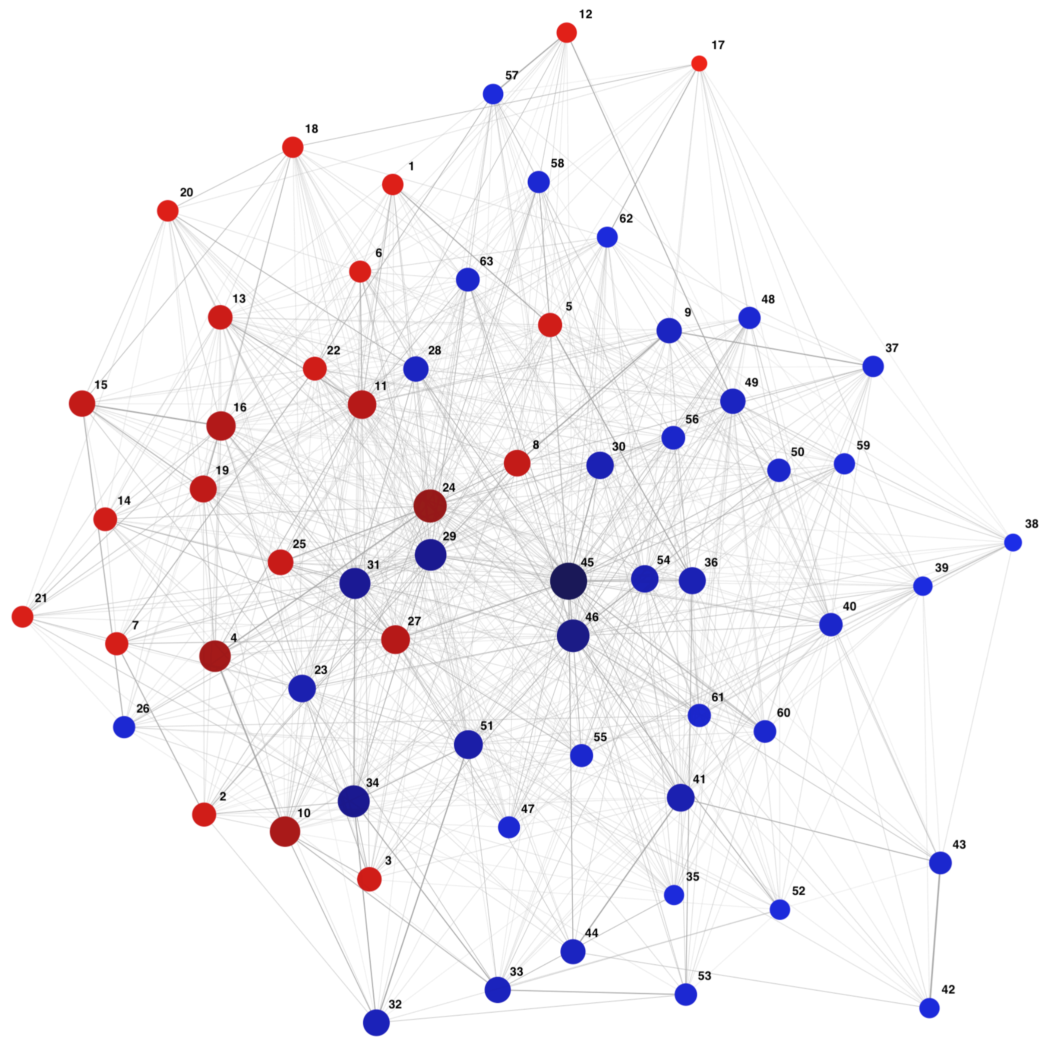

Figure 3. Detailed network structure of the Estonian multisectoral economy in 2015.
Note: Each vertex represents a sector, with size and darkness corresponding to eigen centrality scores. Blue colour indicates services-related sectors. Edges are visible if a transaction is above 1% of a total input required by a sector.
Source: Eurostat data, own calculations.

Figure 3 gives us broad, general overview of all the input-output relations between sectors in Estonia. From this perspective, the network structure resembles the complete network model (where all vertices are interconnected with each other). Closer look allows to differentiate the outskirt sectors connection structure (only few visible edges for some of them) from connectedness of sectors one layer closer to the middle, which seem to have more direct edges. However, the centre of the graph is not clear enough to determine the leaders in terms of number of relations to other sectors just by counting the edges.

Another eye-catching observation is the notable position of a few centrally located, darker vertices. The most central roles in this network belong to sector 45, which represents *Real estate services*, followed by *Legal and accounting services* (46) and energy sector (24). It seems, that in the case of Estonia, most central sectors are service-related (this is further quantified in the following chapter).

The next step to gain valuable insight into Estonia intersectoral structure is to analyse a general network of sectors. Somewhat paradoxically, by generalizing graph to focus only on strongest connections, a new perspective on sectors' interaction can be gained. Therefore, introducing tighter restrictions on what edges will be visualised allows for more focused investigation.

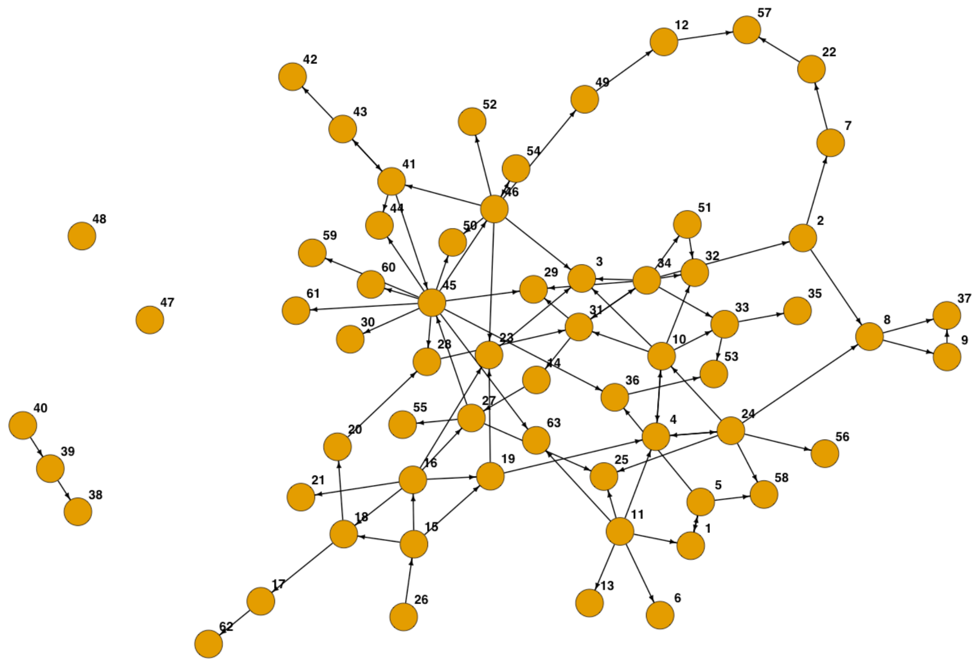

Figure 4. General network structure of the Estonian economy in 2015.
Note: Unweighted, directed graph is presented, with edges visible if input transaction is greater than 10%.
Source: Eurostat data, own calculations.

Figure 4 illustrates general structure of intersectoral network based on input-output matrix calculated for Estonian data from 2015. Only transactions above 10% of input to a sector are depicted. It is unweighted (all edges have the same width despite different values of w_{ij}, as long as it is greater than 0,10) and directed, which means that an arrow indicates which sector supplies to which. Again, the transactions originating in the same sector are excluded. At first glance it is apparent, that the structure does not resemble the complete network anymore. In fact, a variety of network shapes described by a relevant literature can be spotted in the picture of Estonian economy.

Firstly, on the left side of the graph, some sectors seem to be disconnected from the main structure. The two sectors without strong input-output relations to any other are *Architectural and engineering services* (47) and *Scientific research and development services* (48). From the perspective of shock propagation, this is an example of independent sectors allowing for a classic *diversification argument* to hold. The economy consisting of only such single out sectors would be called *pure horizontal* (Bigio, La'o 2016, 2020) and is often used when modelling production function (and aggregate consumption) in macroeconomic literature.

Secondly, there is a linear structure consisting of three sectors forming one-directional value chain, which is separate from the main network. *Computer programming, consultancy and related services; Information services* sector (40) seems to be key supplier for *Telecommunications services* (39) sector, which is further a vital supplier to *Motion picture, video, tv programme production and publishing, broadcasting services* (38). This is an outstanding example of a supply chain, called by Bigio and La'o (2016) a vertical economy. There is an evident upstream sector, whose output is transformed via middle sector, which in turn supplies extensively to the final, downstream sector – RTV (or rather electronic entertainment) in this case from Estonia. This is also a visual proof of a success story described by Hogselius (2002). Indeed, strong linkages between software companies and Telcom value chain has been established, creating a robust cluster.

Carvalho (2014) shows that in vertical economy, a sector being a single source (most upstream) plays the biggest role in propagation of idiosyncratic-shocks in the economy, with subsequent sectors having less and less impact on aggregate fluctuations and the sink (most downstream sector) having least propagation potential. In the example of analysed IT supply chain this argument seems to hold, when tested empirically. Sector 40 has the highest corresponding value in an influence vector of the economy (related to centrality score) and ranks 22nd among all other sectors, sector 39 ranks at 48th place whereas sector 38 is one of the most peripheral sectors in Estonian economy according to centrality scores (rank 61). In Chapter 3 more elaboration on the role of influence vector is presented.

Finally, looking at the main network architecture, one can make a variety of observations depending which sectors or clusters are in the scope of the analysis. For the purpose of this essay and the topic of shock propagation, there are two notable examples, which can further clarify how the arrangements of vertices and edges can indicate existing shock propagation mechanism. The examples are depicted on Figure 5.

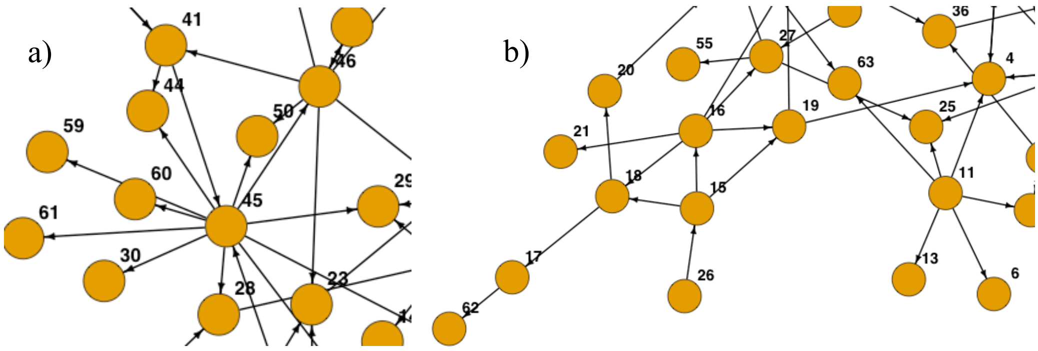

Figure 5. Two segments of Estonian intersectoral network of particular meaning for shock propagation mechanism.
Source: Eurostat data, own calculations.

Above illustrations are just two sections of the network from Figure 4, zoomed and panned to allow more explicit reasoning. In the middle of the Figure 5a *Real estate services* sector (45) is situated. With many strong output relations, this sector resembles star-like structure (Acemoglu et al. 2012). On the first sight, it is apparent that exceptional outdegree level of this sector contributes towards direct shock propagation in the economy. Moreover, as was highlighted in Section 2.2., this is the sector with highest centrality score, which suggests its important role of a higher-order shock transmitter. As pointed out by Carvalho (2012), star economy (one general purpose technology central sector, whose input is used by all other sectors) yields more impact on aggregate volatility than any other shape of production network. Although the Estonian intersectoral network most certainly does not resemble model of a star, calculations confirm important role of *Real estate services* sector as contributor to aggregate fluctuations.

Lastly, Figure 5b depicts a fragment excerpted from the main network to show how idiosyncratic shocks might propagate in the value chain, which shape does not necessarily approximate one of theoretical patterns. Sector 26, *Sewage services, waste collection, material* *recovery systems etc.,* has a single, strong upstream connection with *Basic metals* sector number 15. However, basic metals sector provides essential input to three other sectors, playing essential roles of intermediaries in value chains going through the whole economy[17]. This indicates how seemingly peripheral sector can play pivotal role in transmitting an idiosyncratic shock to key sectors via higher order interconnections[18].

Latvia

The middle Baltic State, in terms of geographical location, population and aggregate production, went through economically dynamic path after EU accession, shortly described by Blanchard et al. (2013) as the "Boom-bust recovery". After a rapid GDP growth period, outpacing Lithuania and Estonia in 2006 through 2008, the financial crisis struck the country particularly hard. As a result, Latvia required additional year to recover and in 2010 fell below Lithuania in output *per capita* statistic. From then on, the growth pace was on average lower compared to other Baltic republics[19].

The academic evidence on Latvian sectoral network composition is scattered in several, not closely related sources. Mihnenoka and Senfelde (2017) analyse structural transformation looking and wages and employment by sectoral disparities in the country. They note that employment structure remains remarkably stagnant over the years and Riga region, specialising in finance, transportation and ICT, is clearly disconnected with the rest of the country specialising in low value-added activities, mainly agriculture. Among similar observations on regional polarization, Sipilova (2014) acknowledges consistently strong position of non-tradable goods sectors with low productivity and, interestingly, points out to high output variations in short periods of time.

Benkovskis et al. (2019) analyse a dissimilarity between Estonia in Latvia in terms of benefits from Global Value Chains participation. Their empirical study confirms positive effects stemming from *learning-by-exporting* hypothesis in those countries, however in Latvia a smaller proportion of firms engage in international trade and those which engage tend to be goods exporters (as opposed to Estonia, where the portion of services and goods exporters is

[17] Those sectors are *Electrical equipment* (18), *Fabricated metal products* (16) and *Machinery and equipment n.e.c.* (19).

[18] This example may be a little unfortunate in the sense that Sewage and waste collection sector has rather strong impact on everyday life, therefore direct shocks could be much more noticeable, at least in a short term.

[19] According to The World Bank database, constant 2010 US$ term (2010-2019 period).

close to one) or transport services-related. This hints that Latvian sectors my not utilize development potential in a similar tempo to Estonian.

Watkins and Agapitova (2004) provide comprehensive outlook of Latvian intersectoral structure prior to EU accession. They illustrate several dimensions in which Latvia seemed to be falling behind, compared to other CEE countries, such as employment share in high-tech manufacturing and services, inter-industry trade with EU members or technology-driven industry share in the market. The relative strength in wood industry was not reliant for structural development because it mainly involved minimal processing activities. Grassini et al. (2006) further investigate multisectoral structure of the country, stress the importance of the rebuild process after post-transition production collapse and point to fast growing storage and transport services as an answer to domestic demand. Koyama (2010) attempts to follow the shock propagation channel in banking sector in 2008 and concludes, that the significantly larger proportion of domestic banks (i.e. less FDI in this sector) compared to other Baltic States could contribute to worse outcome of the financial crisis. Sipilova (2015) brings up interesting argument, that a mismatch between wage-driven educational preferences and optimal intersectoral development path in Latvia may contribute to slowing down of the latter.

Figure 7 illustrates the detailed structure of Latvian economy, based on Input-Output relations between sectors in 2015. On the first look in resembles Estonian graph – almost complete network with a couple of central hubs in the middle. To gain a better perspective, one has to pay attention to the details of the illustration. On the left side of the picture there several small vertices with low labelling numbers, corresponding to primary sector. It hints that the regional divergence (Mihnenoka, Senfelde 2017) is present also in terms of sectoral interdependencies within production process – primary sector does not have multiple connections with the rest of the economy. When looking at the darkest vertices in the middle of the structure, the most central sectors can be identified. In Latvia, services-related sectors are among the very central, similarly to Estonia. However, the most likely shock propagators seem to be *Wholesale trade services* (29) and *Warehousing and support services for transportation* (34), which have almost identical eigenvalues.

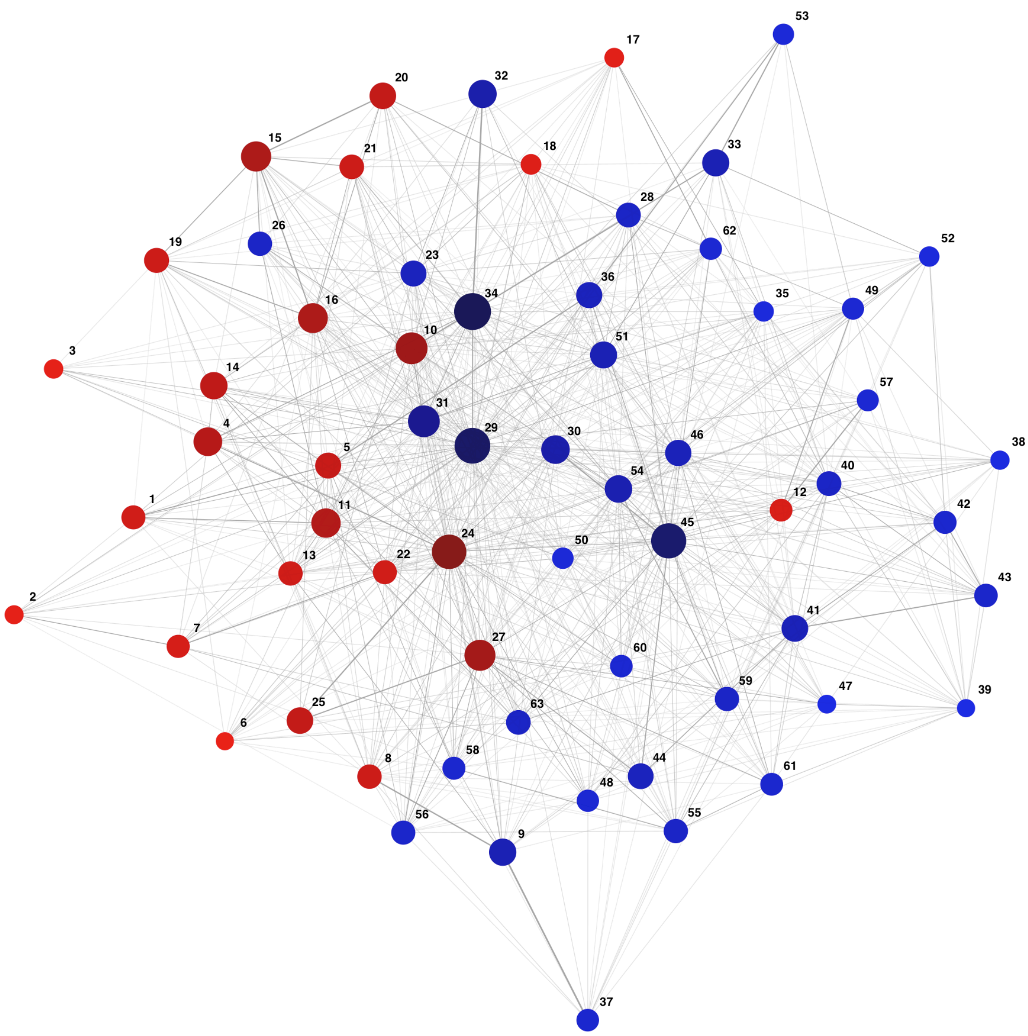

Figure 7. Detailed network structure of the Latvian multisectoral economy in 2015.
Note: Each vertex represents a sector, with size and darkness corresponding to eigen centrality scores. Blue colour indicates services-related sectors. Edges are visible if a transaction is above 1% of a total input required by a sector.
Source: Eurostat data, own calculations.

Figure 8 gives perspective on the most important connections in the Latvian production chains. There are five sectors without strong relations to the rest of the economy. Apart from fishing and textile production related activities, three technology-intensive sectors are disconnected from the production relations: *Electrical equipment* (18*), Telecommunications services* (39) and *Other professional, scientific and technical services and veterinary services* (50). Moreover, there seems to be a vertical value chain, very similar to ICT in Estonia. It consists of three sectors: 2, 7 and 22 which constitute for forestry industry, wood related activities and furniture manufacturing. This might illustrate a positive conclusion to a threat illustrated by Watkins and Agapitova (2004): it seems that the industry was able to evolve from being concentrated on minimal processing of wood products and establish robust linkages enabling furniture production. A focused analysis might reveal, if those activities are export oriented and take part in a major global value chain, which would allow for further industrial development through spillovers.

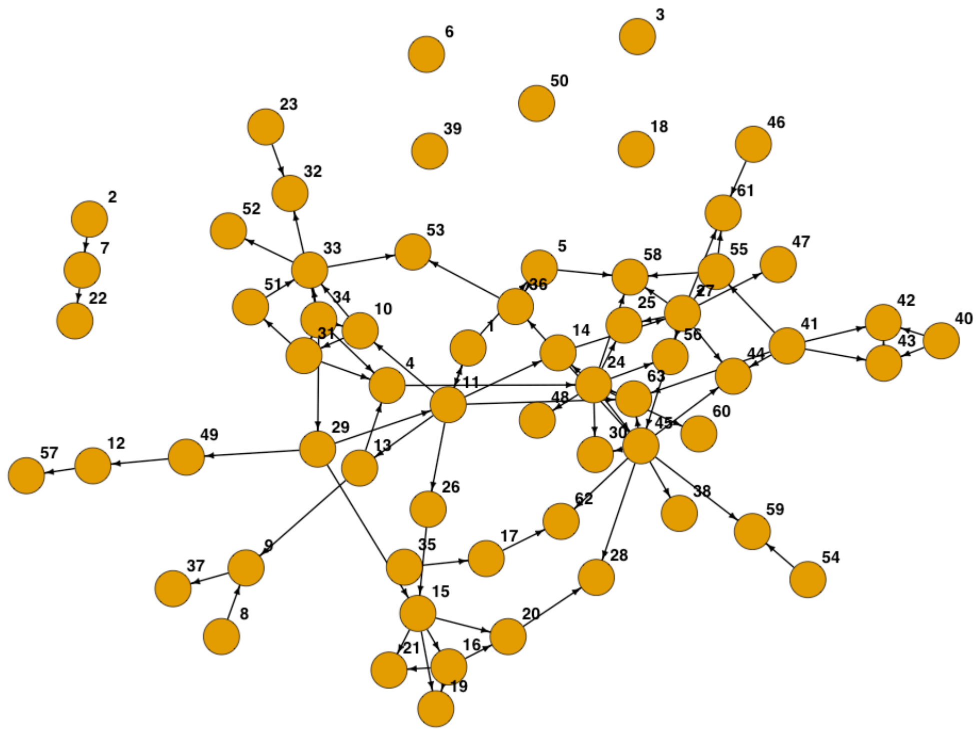

Figure 8. General network structure of the Latvian economy in 2015.
Note: Directed, unweighted graph with edges visible if transaction is greater than 10% of a required input.
Source: Eurostat data, own calculations.

Lithuania

The biggest Baltic economy, Lithuania, inherited parts of Soviet supply chains which had to be facilitated somehow in a new economic model. It was not an easy task considering low quality of manufacturing, broken linkages and a demand void after parting with the USSR (Abdelal 2018). Moreover, some industries had to face shocks of price adjusting after subsidies on raw materials and energy ended. However, according to the World Bank data for 1990, the share of agriculture sector in Lithuania was considerably bigger than in other Baltics, whereas industry share was lower. This could have been beneficial in a short term, as manufacturing was much more affected by supply chains disintegration. Another interesting perspective on early structural transformation in Lithuania was a historically long and ambiguous relationship with Poland, which was crucial partner when considering plans of western economic integration (*Ibid.*). Fortunately, joint diplomatic effort allowed for quick decisions on cooperation to foster economic structure transitions.

Tvaronaviciene and Ginevicius (2003) gathered early evidence on FDI impact of the sectoral structure of Lithuanian economy. They highlighted FDIs' ambiguous effect on output, positive in services-related sectors and negative in industry. Rybakovas (2009) assessed productivity and competitiveness of Lithuanian manufacturing to find that the industry is almost five times less productive than the EU average. Despite that, there were some hints of comparative competitiveness in food, wood and textiles sectors. Saboniene, A. (2011) investigated changes in manufacturing between 1998 and 2009 to find that manufacturing in low technologically intensive branches preserved the two-thirds share of all value added by the industry, medium-low tech actually increased the share, while the proportion of medium-high and high technology intensive manufacturing decreased compared to 1998. Tvaronaviciene (2014) noted, that such manufacturing structure requires considerable energy input, which could be problematic to supply in a long term. Dudzeviciūte, Maciulis and Tvaronaviciene (2014) assessed the intensity of tertiarization process (shifting value added source in the economy toward services) and found the Lithuania was a global leader in 1990-2011[20]. Startiene and Remeikiene (2014) examined comparative advantages of Lithuanian industries. After a particularly strong decline of trade during financial crisis, the most competitive sectors were textile, food, wood and chemicals manufacturing (not a big change compared to Rybakovas (2009) results). Finally, Constantinescu and Barauskaite (2018) investigated the topic of micro-shocks transmission in Lithuanian intersectoral network to find that variation in outdegrees contribute to aggregate fluctuation in Lithuania. Authors however did not include analysis of the network structure, which could shed some light on the propagation channels.

Figure 9 presents the network of intersectoral relations in Lithuania based on the most recent input-output data. The visible difference of the structure, compared to the two other Baltic States, is the composition of the middle of the graph, consisting of the most central vertices. It is a mix of primary, secondary and tertiary sectors, not forming clear clusters (like in Latvian example). The most central nodes are *Wholesale trade services* and *Real estate services* (accordingly 29 and 45), followed by *Electricity, gas, steam and air conditioning* sector (24). However, among the top ten central nodes, there are also: chemical and petroleum industry (10+11)[21], mining related activities (4) and food industry (5). This indicates that two

[20] This should be treated rather as a general hint that the process was fast, given lack of authors explanation on the actual control sample (only broad country grouping presented)

[21] Only aggregated data is available for those sectors in Lithuania, see Table 6A in the Appendix.

out of three most competitive Lithuanian industries identified by Rybakovas (2009) and Startiene and Remeikiene are well connected with the rest of the economy. The wood sector seems to have weaker production technology relations.

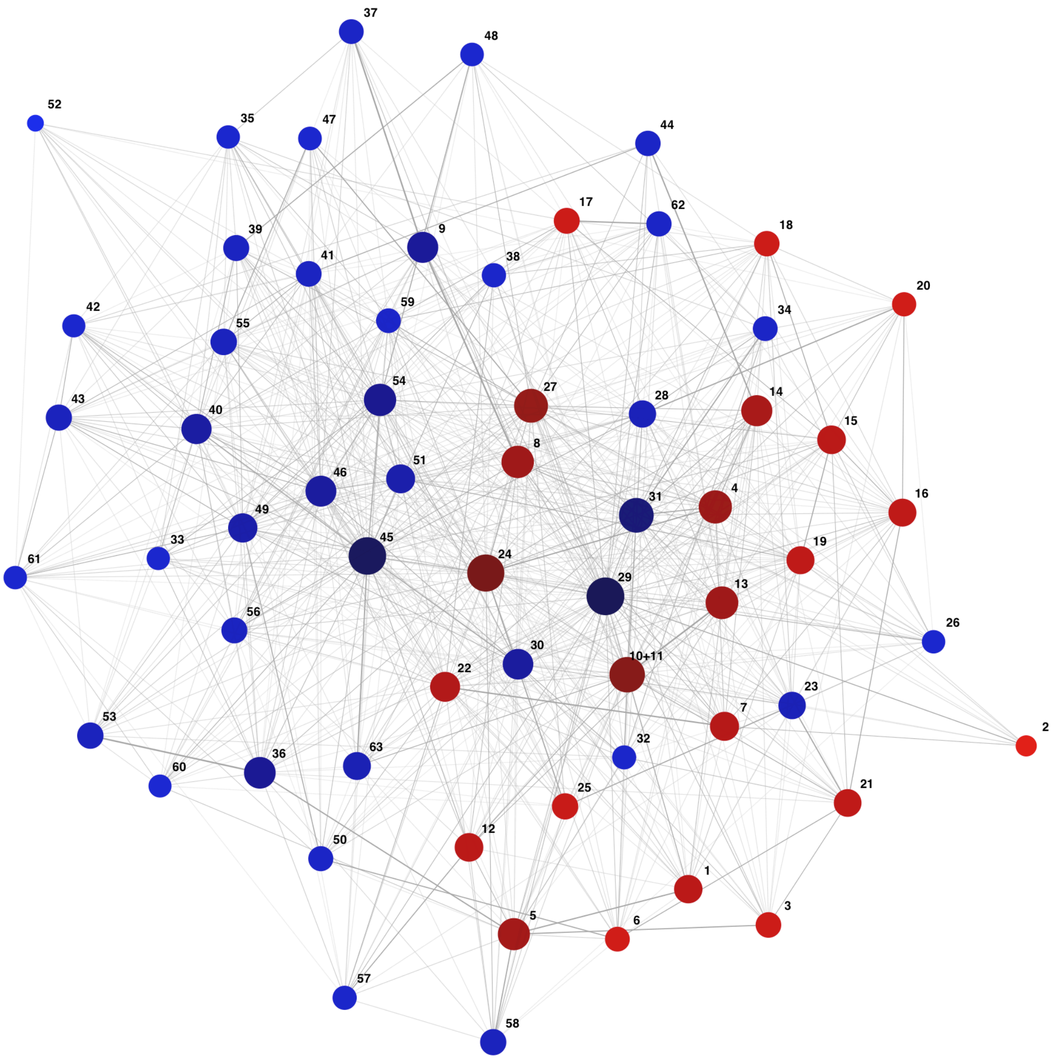

Figure 9. Detailed network structure of the Lithuanian multisectoral economy in 2015.
Note: Each vertex represents a sector, with size and darkness corresponding to eigen centrality scores. Blue colour indicates services-related sectors. Edges are visible if a transaction is above 1% of a total input required by a sector.
Source: Eurostat data, own calculations.

Figure 10, presenting the general graph of the strongest input-output relations in the Lithuanian economy, is quite outstanding compared to other country general graphs constructed for this study. The algorithm employed to clearly distribute vaertices and edges failed. Messy structure hardly allows to make any observations on the value chains positions. This may hint, that a majority of sectors have connections with many central hubs and only a few have a single connection. Additionally, only two sectors do not have a strong input-output relation with any other: *Employment services* (52) and *Postal and courier services* (35)

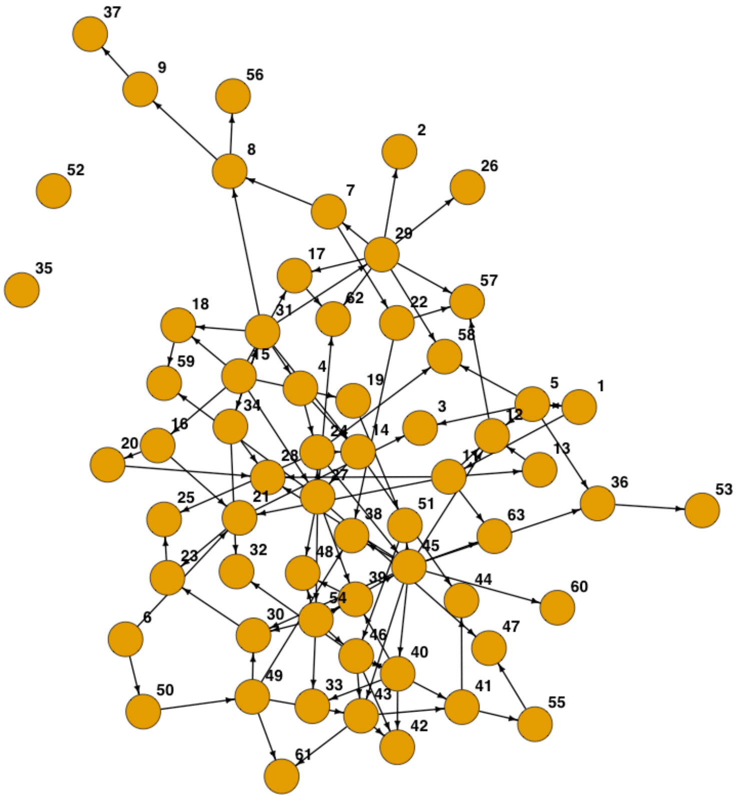

Figure 10. General network structure of the Lithuanian economy in 2015.
Note: Directed, unweighted graph with edges visible if transaction is greater than 10% of a required input.
Source: Eurostat data, own calculations.

Czech Republic

After the Velvet Revolution in 1989 Czechoslovakia was not as much of an open market as Poland or Hungary, with almost all economic activity under state ownership. However, it enjoyed more initial economic stability in terms of inflation and budget state[22] (Dyba & Svejnar 1995). Nevertheless, the output decline in 1994 was significant in Czech Republic. The reason was a heavy industrialisation of the country – relatively high shares of metallurgy and machinery production (this is opposed e.g. to the previously described Lithuanian situation). Bohata, Hanel and Fischer (1995) point to an early shift from manufacturing sectors (especially machine industry) towards mining and energy sector, caused correspondingly by a demand fall and raw material supply shock after decoupling with the Soviet Union. According to the

[22] This is until a series of trade shocks: losing western partner after Germany unification, collapse of the Soviet Union and splitting of Czech and Slovakia in 1993. Soon afterwards, the innovative privatisation process begun (Koyame-Marsh 2011).

authors, Czech Republic needed to "replace the exceedingly vertically-integrated industrial structure inherited from the past regime" at that time.

Sorm and Terrell (2000) analysed intersectoral labour flows in 1989-1999 and found that the shift from agriculture and manufacturing sectors to construction, wholesale and financial services was much stronger in Czech Republic than in Estonia or Poland. At the same time, the unemployment stayed at relatively low levels, proving flexibility of the Czech labour market and readiness for restructuration, possibly greater than other transition economies. Kippenberg (2005) evaluated evidence on how foreign investments in Czech Republic impacted the sectoral composition via emerging linkages. She found that labour-intensive sectors and manufacturing sectors are on average more likely to benefit from FDIs than capital-intensive sectors. Kippenberg (2008) focused on regional concentration of sectoral activity in Czech Republic. The author stated that the increasing regional divergence stems from decline in output and employment in the eastern, industrial regions of the country, and urban centres seem to concentrate tertiary activities. Hedvicakova and Kral (2019) evaluate the state of the Czech industry and point to low efficiency and lacking long-term investments in the dominating car manufacturing industry, while other, seemingly marginal sectors, such as beverages production, may turn out to be strategically more important in the future industrial development in Czech Republic. Sujova and Hlavackova (2015) documented declining competitiveness and insufficient development of wood processing related sectors. Vlckova, De Castro and Antal (2015) consider Czech Republic's positioning within Global Value Chains. Despite relatively low productivity and value added of domestic services sector, the progress in areas such as Research and Development and competitiveness is substantial. Pavlinek and Žižalova (2016) conducted remarkably comprehensive analysis of the spillovers through backward and forward linkages in the Czech automotive industry based on microdata of first- and higher-order suppliers. From the number of interesting observations, the following gives a hint to the process of the industry network formulation in Czech Republic: vertical spillovers were not enough to establish a robust, self-sufficient structure of domestic suppliers. This is mainly because of inability (or mere ineffectiveness) of creating a broader network of multisectoral production chains, sufficient to cover a meaningful part of the manufacturers GVC. Therefore, it is not expected that car manufacturing industry will be one of the central vertices of the input-output network.

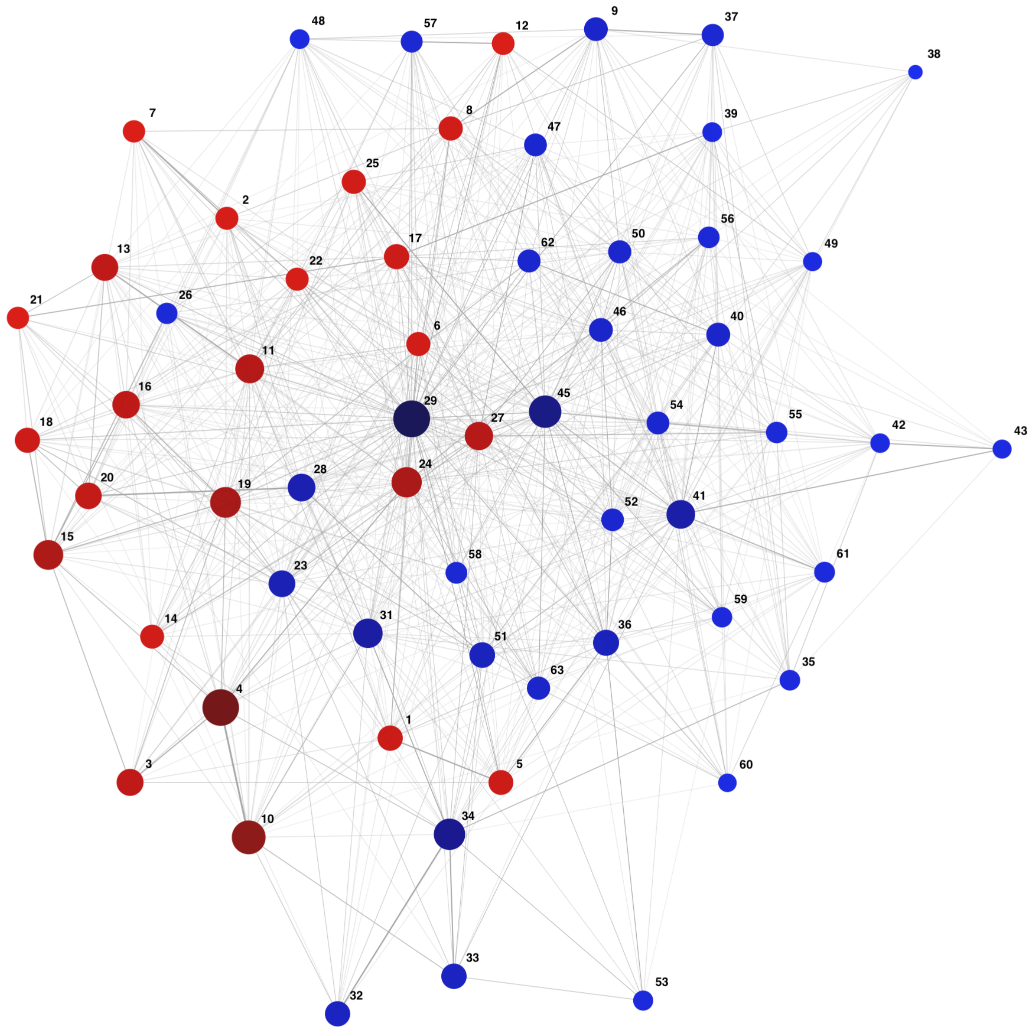

Figure 11. Detailed network structure of the Czech Republic multisectoral economy in 2015.
Note: Each vertex represents a sector, with size and darkness corresponding to eigen centrality scores. Blue colour indicates services-related sectors. Edges are visible if a transaction is above 1% of a total input required by a sector.
Source: Eurostat data, own calculations.

The intersectoral network of Czech Republic economy seems quite symmetric, with only a few heavier central vertices. Node with the most direct edges and in the same time, with the highest eigen centrality value (which takes into consideration also higher-order connections) is the *Wholesale trade services* sector (29), later followed by *Mining and quarrying* (4) in terms of centrality[23]. The latter additionally accounts for the highest input supplier in the whole networks, visible on the graph as a wider edge between sectors number 4 and 10. This illustrates that *Coke and refined petroleum products* sector (which is one of the

[23] In terms of first-order connections, this sector ranks 9th. Much higher position in centrality ranking indicates, that other central hubs rely heavily on its' output (possible cascade shock channel).

most central sectors in the Czech economy structure as well) uses 78,5% of the sector 4 input in its' production technology.

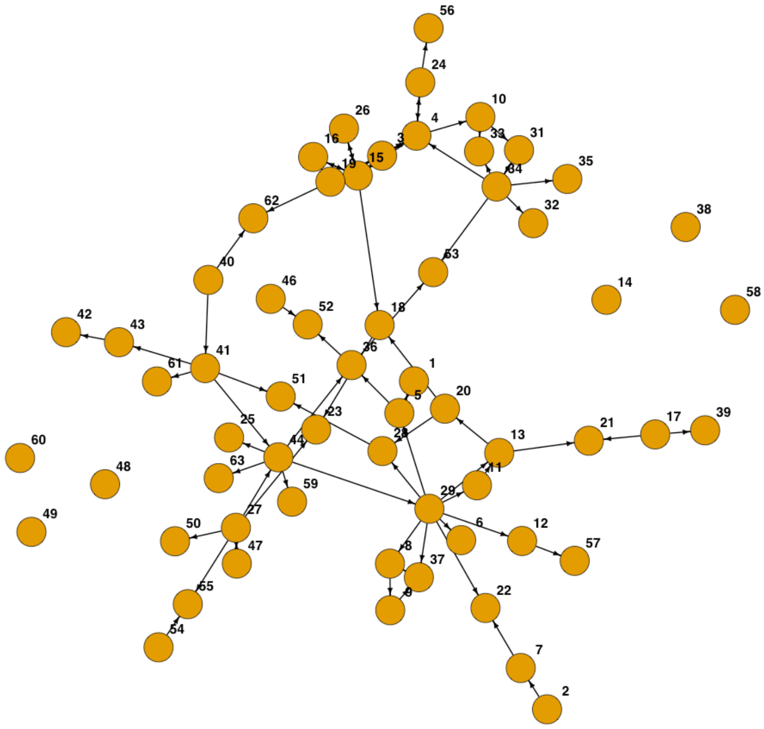

Figure 12. General network structure of the Czech Republic economy in 2015.
Note: Directed, unweighted graph with edges visible if transaction is greater than 10% of a required input.
Source: Eurostat data, own calculations.

Above, a general structure of the production chains in Czech Republic is presented (Figure 12). The illustration is much clearer than the previous for Lithuania, allowing to distinguish architectural features more precisely. There are six sectors disconnected from the main structure, which seem to be unrelated and mostly peripheral[24]. The upper part of the graph contains heavy industry and transportation value chains, while the wholesale sector in the bottom act as start-like structure, connecting car industry, wood processing sectors, medicine production and publishing related cluster. Overall, although the structure is relatively clear, there is no obvious propagation centre in the structure on this level of illustration specificity.

[24] The disconnected sectors are: *Other non-metallic mineral products* (14), *Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services (38), Scientific research and development services* (48), *Advertising and market research services* (49), *Residential care services; social work services without accommodation* (58), *Sporting services and amusement and recreation services* (60)

Hungary

The home state to the Visegrád castle, where the V3 group[25] was established in 1991, had a significant head start in terms of market transformation process after collapse of the Soviet Union when compared to other transition countries. Domestic enterprises had comparatively more autonomy for over two decades before the fall of the communistic system and until 1991 the prices were fully liberated and foreign investments flowed to the Hungary in large volumes (Brada, King, Ma 1997). The country's intersectoral network still needed to go through substantial reconfiguration however. Hasan and Marton (2003) positively rate the early privatisation and development of Hungarian banking sector, although they remark the sector had not deepened enough to evaluate it comprehensively at this stahe. Thirtle (2000) found substantial fall in Total Factor Productivity of agriculture and manufacturing sectors between 1985 and 1991, which were caused by technological decline in Hungary. Schoors and Van Der Tol (2002) report early evidence of FDIs' positive intersectoral spillovers originating from emerging forward linkages. This hints a promising starting point to the sectoral restructuration. However, Hamar (2004) noticed, that although extensive foreign capital flow and settling down of MNCs boosted broader macroeconomic outlook of the country, there is evidence of emerging dualistic economy: foreign companies affiliates were prioritized over fostering the domestic businesses growth, especially in manufacturing sectors. Radosevic and Roziek (2005) stressed the potential of utilizing foreign presence in Central European countries to create knowledge and production linkages with other sectors within their economies. To achieve this, it is vital to facilitate the integration of domestic companies with foreign affiliates. The authors highlight the role of Integrator programme in Hungary and propose EU wide similar initiative.

Egedy (2012) pointed to possible intersectoral shock transmission during financial crisis. The author distinguished two channels: The most severe effect in terms of employment decline was in the construction and real estate services. On the other hand, the financial sector originating crisis affected respectively engineering, automotive and electronics sectors. On the other hand, Sass and Szalavetz (2013) argue, that the crisis triggered an upgrade in car manufacturing and electronics sectors and fostered supply chains restructuration, with foreign MNCs affiliates at the frontier of those changes.

Lengyel et al. (2017) do not find evidence of post-crisis reindustrialisation in Hungary, apart from scarce clues in two rural regions. Moreover, the authors estimate further

[25] The Group become V4 after the Czech and Slovak dissolution two years later.

deindustrialisation in the capital and urban regions. Yasmin, El Refae and Eletter (2019) employed input-output analysis to find that the key sectors (with simultaneous highest backward and forward linkages scores) are *Basic metals*, *Electrical machinery* and *Wholesale and trade*.

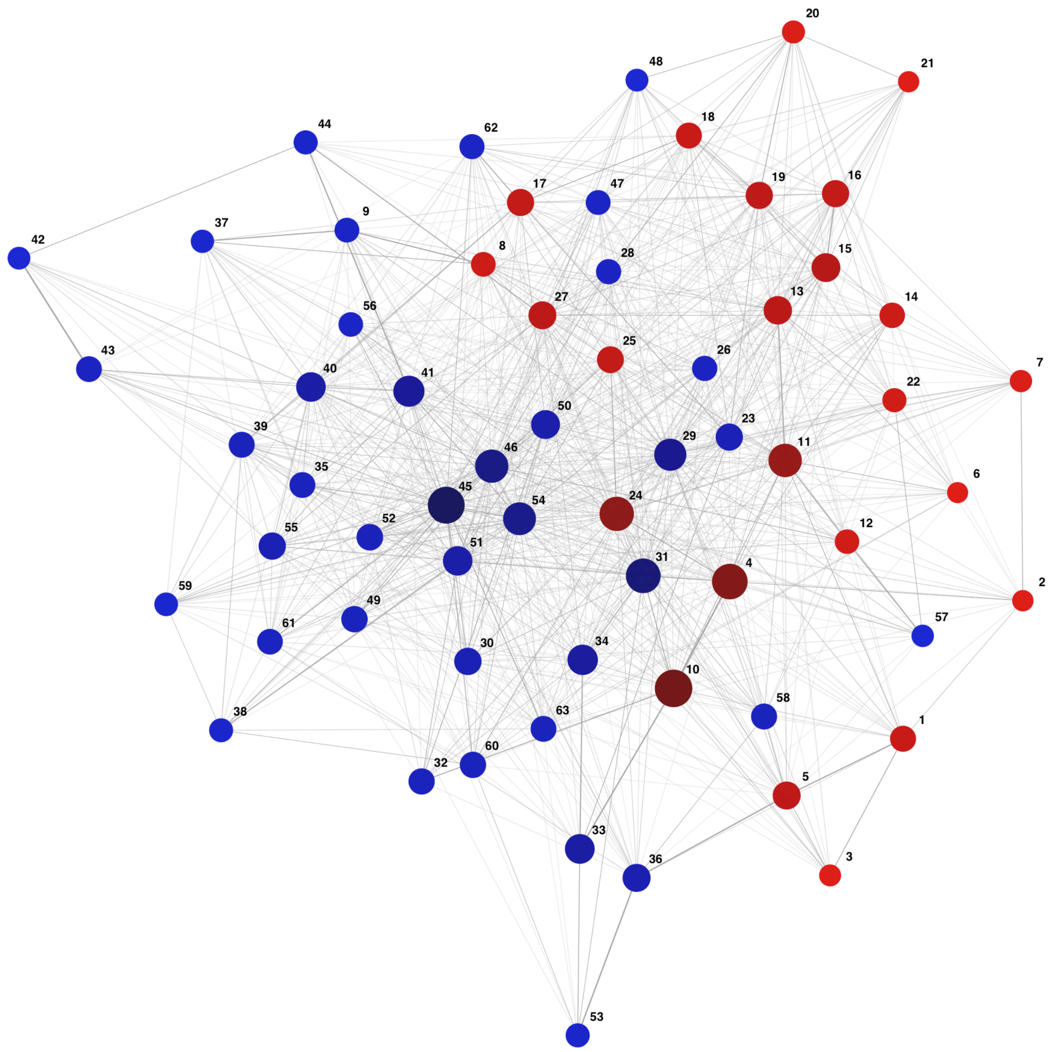

Figure 13. Detailed network structure of the Hungarian multisectoral economy in 2015.
Note: Each vertex represents a sector, with size and darkness corresponding to eigen centrality scores. Blue colour indicates services-related sectors. Edges are visible if a transaction is above 1% of a total input required by a sector.
Source: Eurostat data, own calculations.

Figure 13 contains illustration of all input output relations between sectors in Hungarian economy in 2015. Apart from identifying most central production hubs and the proportion of services-related and industrial sectors among them, it is possible to distinguish some unique features when comparing to previously analysed analogous structure for Czech Republic. Firstly, the overall shape of the intersectoral network seems to be more irregular for Hungary and the spatial distribution of vertices is also less grid-like. This may indicate the presence of strong connection between sectors from mostly divergent clusters and some sectors with only one or few strong connections to others, bringing them closer together. The middle of the graph is dominated by red and blue mixture of dark vertices. *Real estate services* (45) present the highest eigenvector value, followed by *Coke and refined petroleum products* (10) and *Legal and accounting, management consultancy services* (46). The vertical chain of three dark red nodes consists of the subsequent most central sectors apart from number 10: mining (4) and chemicals manufacturing (11). Finally, the quadrangle structure outstanding on the upper-left side of the illustration is the finance-insurance-related cluster.

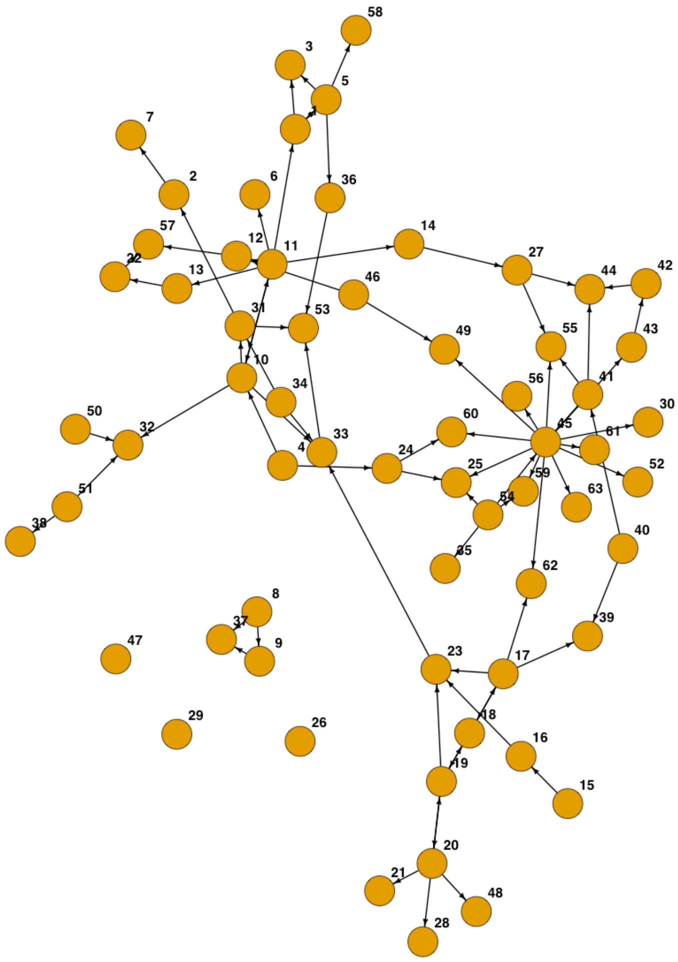

Figure 14. General network structure of the Hungarian economy in 2015.
Note: Directed, unweighted graph with edges visible if transaction is greater than 10% of a required input.
Source: Eurostat data, own calculations.

Figure 14 gives a decent perspective on the production chains structure in 2015 in Hungary. It consists of the main structure, three single, disconnected sectors and a three-sector publishing-related cluster, disconnected from the main structure as well. Interestingly, sectors without any strong input or output relations in Hunagry are usually firmly positioned in the main structure in case of the analyzed countries, especially *Wholesale trade services, except of motor vehicles and motorcycles* sector (29). The main structure is quite clear, with well-established automotive industry on the bottom of the picture. It seems that it managed to develop strong relations within the whole domestic supply chain, as it was discussed in Radosevic and Roziek (2005). However, this also indicates that a shock to *Motor vehicles, trailers and semi-trailers* might propagate strongly to four other sectors and affect the whole output of the economy.

Poland

The biggest economy of the EU's New Member States experienced exceptionally low volatility of aggregate output since the collapse of the Soviet Union. Even the financial crisis of 2008 did not knock out the country from the steady growth path[26] and the post-pandemic recession in 2020 is expected to be one of the smallest on the continent (European Commission 2021). Poland went through the very dynamic transition and privatisation process in the spirit of the *Washington Consensus.* Until 1991, the intersectoral relations in the country were stable (Roberts 1995). Apart from the typical features of FSU economy (which included overdeveloped industry, weak services sectors and lack of labour specialising in knowledge-intensive services) Balcerowicz (1994) highlighted some distinctive initial conditions in Poland. Macroeconomic situation in 1990 was dire compared to Czechoslovakia and Hungary. The country was approaching hyperinflation and had a massive foreign debt. Considerable political influence of worker unions (also at the central level of economic policy through 'Solidarity') could hinder the market liberalisation reforms. From the structural perspective - agriculture situation was specific, with relatively high proportion of private farms ownership but immense fragmentation of the farmland. Estrin and Richet (1993) provided case-study evidence of how weak position of managers and lack of managerial skills, parallel to the empowerment of workers, affected negatively early privatized Polish enterprises. Blanchard (1994) positively assessed comprehensiveness of early reforms by Polish government although

[26] According to the World Bank data, Poland was the only EU country with positive GDP growth rate every year in 21st century (including 2009, when all other EU countries had a negative growth rate value).

Rondinelli and Yurkiewicz (1996) point that the success is fuelled by emerging private SMEs, whereas privatisation of big state-owned enterprises is lagging behind. Slay (2000) listed several observations from the perspective of early intersectoral network restructuring. Agriculture remained problematic. The process of consolidation of small and scattered farms was sluggish and primary sector continued to be ineffective[27]. The construction sector went through gradual but successful privatisation between 1989 and 1995, while the industry lagged significantly behind (in 1995 private sector proportion constituted of 81% in construction and 51% in the industry). The banking sector managed to overcome difficult institutional settings and macroeconomic situation by 1993 and Polish banks were able to compete with foreign affiliates within a range of services. Waters (1999) illustrated the development of retail sector, from bazaars to first commercial chains, and argued, that its' growth rate was exceptionally stable compared to other sectors, uninterrupted by external economic environment and shocks. Dunin-Wasowicz, Gorzynski and Woodward (2004) assessed the industrial networks in Poland from the perspective of FDIs' spillovers and integration with global value chains. They highlighted the early evidence that cheap labour is not sufficient to foster cross-national production network alignment. With little emphasis on research and development from virtually all economic actors, authors stated that the complete reorientation of the domestic network structure is possible after entering the EU. Yoruk (2004) acknowledged the difference in behaviour of clothing sector firms within the industrial networks of Poland and Romania. The author found that in latter country, the firms are knowledge-seekers and cooperate with universities while Polish firms seek linkages only with other domestic enterprises. This hints that the value chain of textile industry in Polish multisectoral network might be less ramified.

More recent analysis provide evidence of how the first decades after economic transition concluded regarding intersectoral network. Swiadek et al. (2019) found that Polish low-technology manufacturing firms tend to limit their cooperation, while medium- and high-tech enterprises cooperate closely with suppliers and competitors and therefore establish wider set of linkages. Olczyk (2011) performed input-output calculations and found that the most value added originate from trade, other services and construction sector. She further investigated the linkages between sectors and noted that the structure remained stable over ten years (1995-2005) while the key sectors constituted of primary sector, transportation,

[27] This remains a long-term problem for Polish primary sector output (see Henningsen 2009), however it does not necessarily contribute to shock transmission in the economy. In fact, it could be argued that excessive diversification of farms may add resilience to the aggregate output of the sector and therefore contribute to lower probability of transmitting a negative idiosyncratic shock.

electricity production and construction. The most interesting take-out from this study is still significant interconnectedness of agriculture within industrial network (despite the issues aforementioned above) and outstanding importance of construction sector compared to other transition economies. Gorska (2015) developed the analysis by incorporating input-output approach into cross-country comparative perspective and employed 2010 data. She found that the primary is no longer among key sectors in Poland and financial and real estate services become one of the most important backward linkage industries. Interestingly, her analysis suggests that structure of multisectoral economy of Poland is quite divergent from other Visegrád countries, which tend to have networks similar to each other. Gurgul and Lach (2015) contributed to the study of sectoral relations in CEECs by adding a time dimension. They found evidence of weakening linkages of manufacturing sectors, while financial services, tourism-related sectors and construction become more firmly interconnected. Unfortunately, the authors aggregated the data for 10 CEE countries, therefore it is not clear which countries are drivers of such changes at to what extent the country-specific networks exhibit the transformation.

The illustration below (Figure 15) presents sectoral network in Poland, which is the result of inherited industrial structure, inward FDIs and 25 years of emerging private business, mortared by market reforms, knowledge spillovers and competition. The architecture of Polish network stands out from the other analysed structures thanks to the dominance of red among the most central vertices. *Constructions and construction works* (27) is a vertex with the highest eigenvector value and also exceptionally bigger role as a direct input provider than any other sector in Polish economy. The *Land transport services and transport services via pipelines* sector (31) is the most central services hub, which is also quite distinctive compared to previously analysed countries, where this role was taken by either sales-related services or real estate.

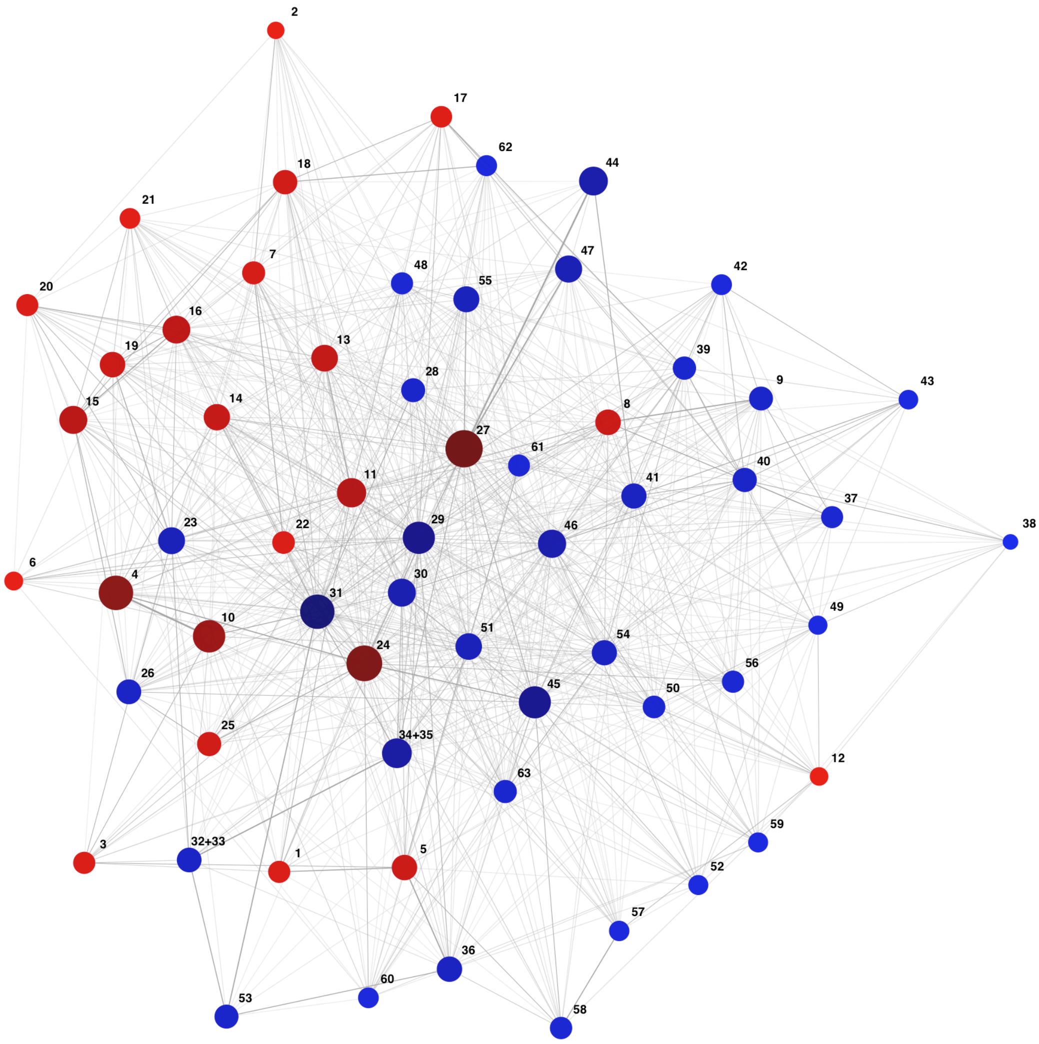

Figure 15. Detailed network structure of the Polish multisectoral economy in 2015.
Note: Each vertex represents a sector, with size and darkness corresponding to eigen centrality scores. Blue colour indicates services-related sectors. Edges are visible if a transaction is above 1% of a total input required by a sector.
Source: Eurostat data, own calculations.

When analysing only the most important production relations between Polish sectors, Figure 16 is a useful visualization. There are six sectors without any strong connections to others, which is a fairly high number, comparable with Lithuania. An interesting case study is the position of sector 6, *Textiles, wearing apparel, leather and related products* among them. This might be the effect of Yoruk (2004) observation, that Polish apparel enterprises are less prone to establishing new linkages compared to their Romanian counterparts. Curiously, the construction sector is not easily distinguishable at this level of illustration detail as a star-like structure (which we could expected after analysing most central vertices in previous examples).

It may mean that the highest centrality score comes from numerous weaker connections to other sectors, as opposed to having for instance only five very strong output relations with other sectors. Additionally, it is a key supplier to other central hubs: energy sector (24) and warehousing (34). Furthermore, the image allows to distinguish some important downstream sectors, relying heavily on the input of several others domestic sectors in their production technology, such as *Telecommunications services* (39), *Publishing services* (37) or *Residential care services* (58). On the opposite, there is an interesting upstream sector at the bottom of the picture, *Chemicals and chemical products* (11). It mainly constitutes of big, majority state-owned companies in southern Poland (Folfas, Udvari 2019) and can serve as shock propagator to other production chains within Polish intersectoral network.

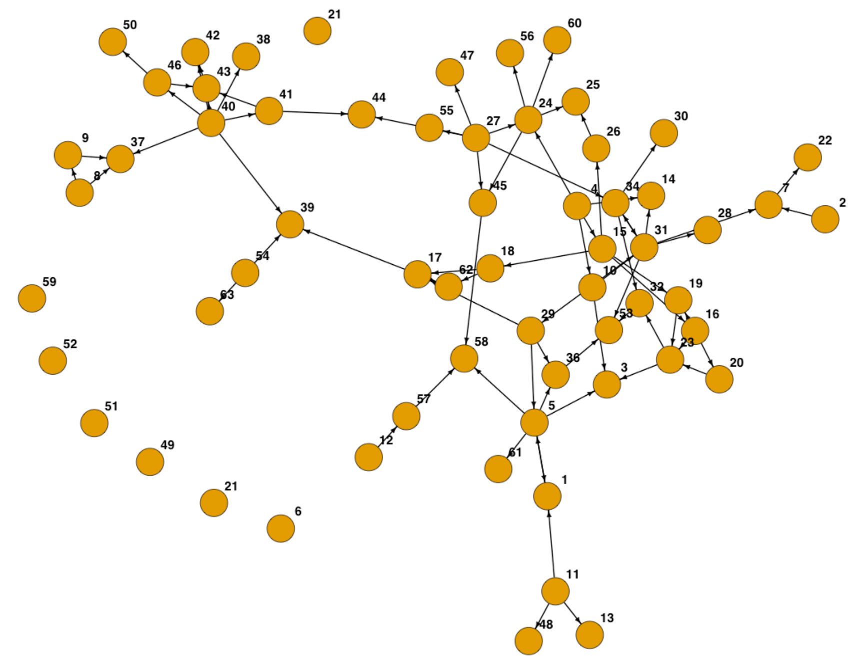

Figure 16. General network structure of the Polish economy in 2015.
Note: Directed, unweighted graph with edges visible if transaction is greater than 10% of a required input.
Source: Eurostat data, own calculations.

Slovakia

The smallest V4 economy started off in 1990 as a part of Czechoslovakia and went through the same early decision-making and its' consequences as Czech Republic. Before the split in 1993, one of a few early macroeconomic divergences between the countries was over three times bigger unemployment in Slovakia, which is an interesting case study given the same starting point of both countries (Dyba, Svejnar 1995). Brada (1991) highlighted that initially some reforms in Czechoslovakia caused difficulties because of the *old ways* of thinking about the economic aims and outcomes, while Balaz (1995) noted, that economic reformists were also under pressure of strong lobbies representing industry and mines, often unprofitable but employing a considerable proportion of regional labour force. Smith (1996) built an argument based on the fact that after well industrialized Czech with Prague (recognized as capital city of Czechoslovakia by foreign capital sources) split form unevenly developed Slovakia, the regional disparities in industrial development in the latter country deepened further because of heavy concentration of relatively scarce FDI inflows in few regions. Pavlinek & Smith (1998) conducted a thorough study of the early MNCs entrants in Czech Republic and Slovakia. They presented mixed results of path dependency evidence of inward FDI destination. However, from the sample of analysed major foreign firms in Slovakia, only one (Whirlpool) built up on and strengthen former industrial network, whereas the rest of the entrants disregarded and replaced with import input required for their production technology.

Recent evidence of intersectoral structure in Slovakia is scare and scattered within varying study fields, however it is still possible to extract some possible hints to the current network architecture. Hudec and Prochadzkova (2018) documented very slow process of knowledge-creation recovery in Slovakian industry and reported prevalent fragmentation of suppliers' networks. At least in Kosice region Sebova and Hudec (2012) assessed positively a transformation of traditionally heavy-industrial specialisation (metallurgy) towards ICT sector and were optimistic about the perspective of forming a new knowledge-intensive cluster. Unfortunately, Elexa et al. (2019) noted lack of state support for cluster creation despite their role in facilitating intersectoral linkages (for example engineering cluster Banská Bystrica region).

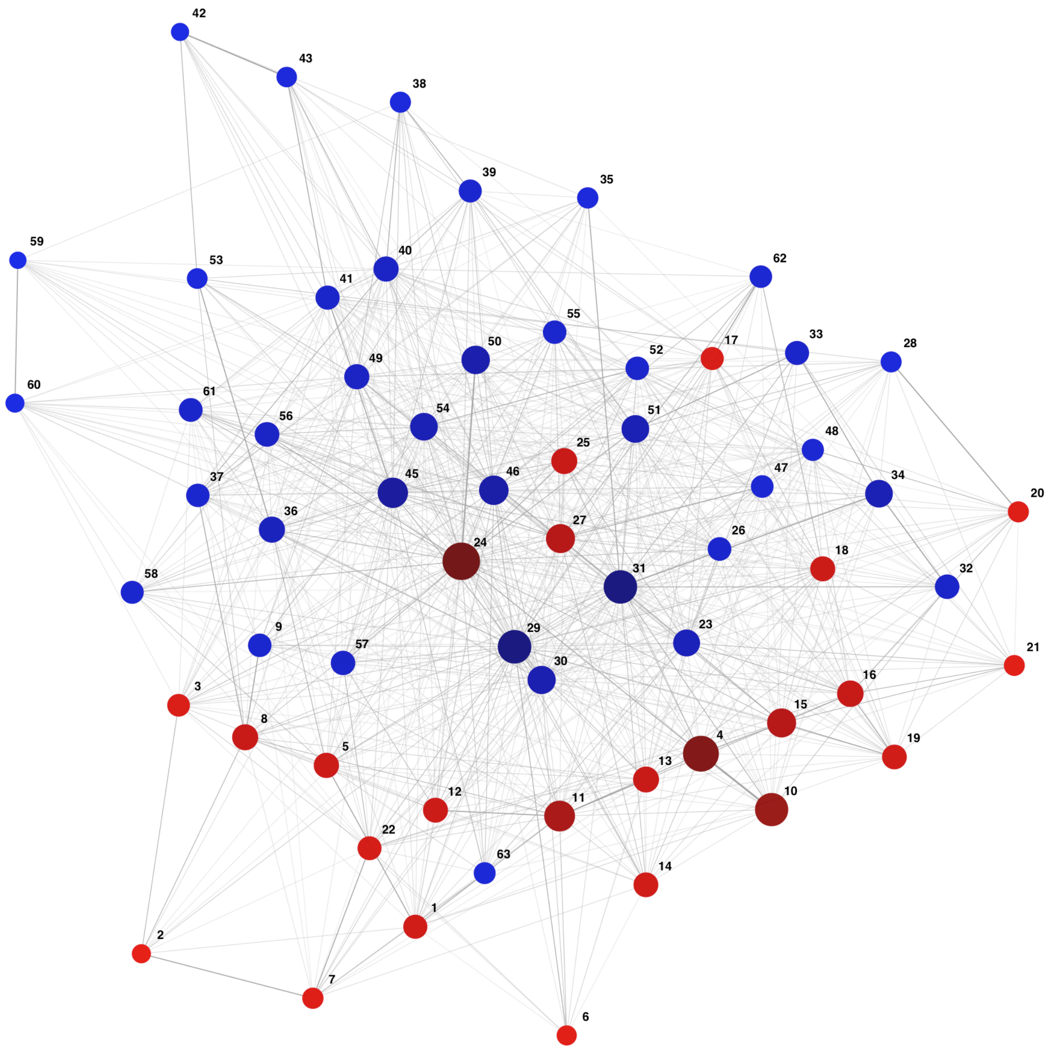

Figure 17. Detailed network structure of the Slovakian multisectoral economy in 2015.
Note: Each vertex represents a sector, with size and darkness corresponding to eigen centrality scores. Blue colour indicates services-related sectors. Edges are visible if a transaction is above 1% of a total input required by a sector.
Source: Eurostat data, own calculations.

Figure 17 reveals interesting properties of Slovakian detailed network of intersectoral production relation in 2015. The general shape resembles a triangle, with one clearly dominant vertex in the geometric middle: *Electricity, gas, steam and air conditioning* (24). The outdegree of this sector (meaning the sum of direct requirements of this sector output in the production of all other sectors) is the highest among all other sectors in each of the analysed countries. Subsequent hub in importance ranking are mining activities (4), while the most central services-related sectors in Slovakian network are wholesale (29) and land transportation services (31).

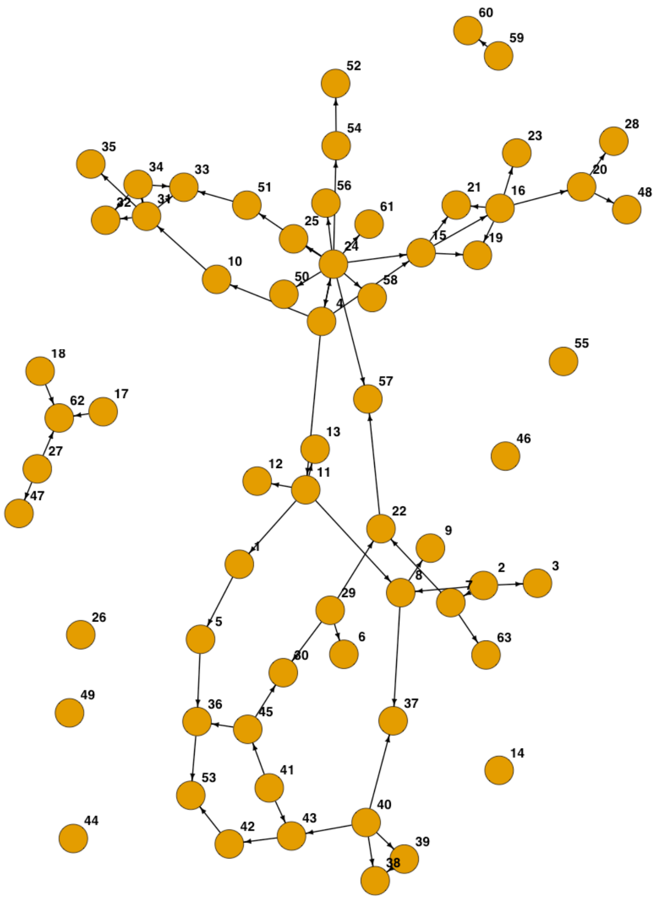

Figure 18. General network structure of the Slovakian economy in 2015.
Note: Directed, unweighted graph with edges visible if transaction is greater than 10% of a required input.
Source: Eurostat data, own calculations.

Finally, the last structure presented in this subchapter is arguably the most interesting one. The "Y"-like (or rather ψ-like) shape of the main network is surrounded by six disconnected sectors, two-sector vertical economy of creative and recreational activities (59 and 60) and a little confusing structure consisting of four sectors, which could be considered a sum of downstream *Repair services of computers and personal and household goods* (62) chain and upstream construction sector (27) surrounding. In the middle of the main network, at the crossroad of four *branches*, there is the energy sector (27), with a whole range of strong output relations. The left branch is a cluster relating to transportation activities (includes water/air/land transportation sectors and other related, such as warehousing or petroleum). On the right there is a heavy-manufacturing group of sectors (e.g. engineering, machinery and metallurgy). The rest of the economy consisting of various industries forms a loop at the bottom of the picture and several sectors, with only one connection to energy vertex, are related to public domain and office services and placed at the top of the picture.

The remarkable position of the energy sector suggests greater vulnerability of Slovakian economy to the related threat. At this level of input-output data aggregation it is impossible to distinguish its most exposed parts and sensitive channels, however if the negative shock resonates within the sector, then the transmission to other parts of the economy is expected to be quicker and stronger than in other investigated transition countries, potentially having immense impact on the aggregate output. Moreover, Weiner (2020) finds a particularly strong position of inward FDI from Russia within the energy sector and Misik (2016) demonstrated the exposure in energy safety because of a considerable dependency from Russian gas.[28]

3.2. Complete analysis of Input-Output matrices

In preceding subsections, the models of intersectoral network were examined. To further develop this analysis and quantify required information, certain statistics can be calculated from previously prepared Input-Output matrices of transition economies.

Although in the centre of attention of this essay are outdegrees (because of the information they provide about shock transmission channels), some additional insight into the structure of the V4 and Baltics intersectoral networks can be gained by investigating it's indegree structure as well.

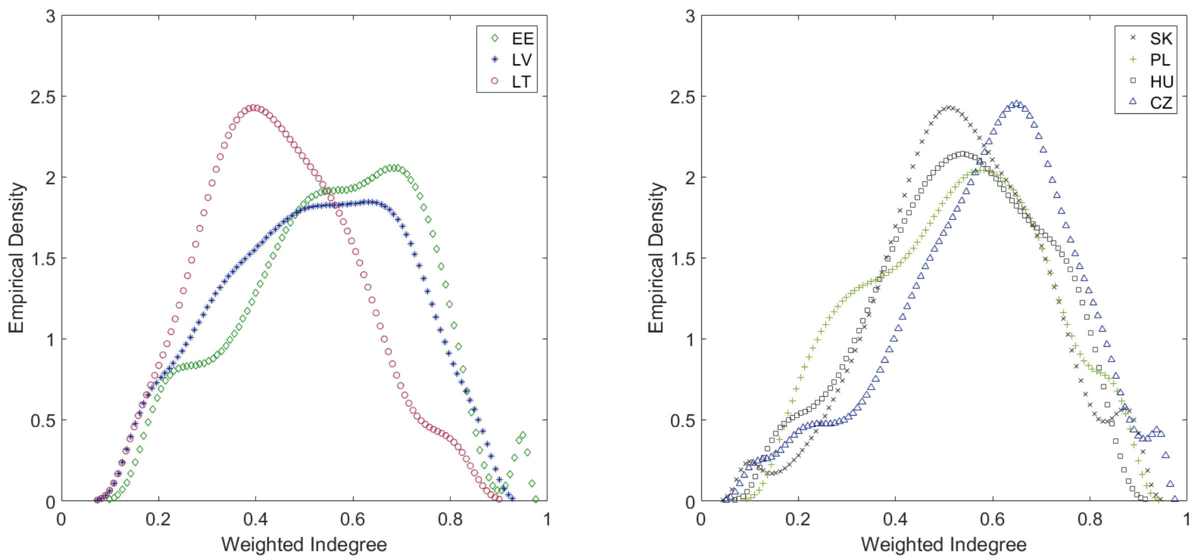

Figure 19. Empirical density of indegrees in the Baltic States and the Visegrád Four countries.
Source: Eurostat data, own calculations.

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[28] To gain more expertise at the issue see Streimikiene, Mikalauskiene, & Mikalauskas (2016) which present some positive evidence from sustainability studies perspective on the potential of energy threat mitigation in Slovakia. For simulation of the economic effects of shock transmission related to gas shortage in Slovakian economy see Fasungova & Radvansky (2014).

Figure 19 presents empirical densities (nonparametric estimates) of the input shares, or indegrees, of each sector. Left panel illustrates results obtained from Baltic economies Input-Output table. The right shows results of similar calculations for four other Central and East European Countries, for which Eurostat provides coherent data; Czech Republic, Hungary, Poland and Slovakia. As demonstrated, the input-intensity vary between sectors and, in addition, vary between countries, where indegree distributions exhibit differing skewness and shapes. Nevertheless, it seems that CEECs, most sectors concentrate their input-share around country mean. The lowest mean indegree can be attributed to Lithuanian Input-Output matrix, the highest to Czech Republic (0,44 and 0,59 respectively). Generally, the average indegree is investigated economies is equal to 0,53 and 67% of observations remain on average within one standard deviation from this value. This means, that an average sector requires more than a half of the total input from other sectors in its production technology.

Advancing to outdegree structure analysis, it is important to clarify, that the matrix has been normalized in order to obtain a stochastic input-output table. This implies that all indegrees are equal to 1, and therefore the value of outdegrees slightly changes. The normalization process plays important role in Chapter 4 analysis[29].

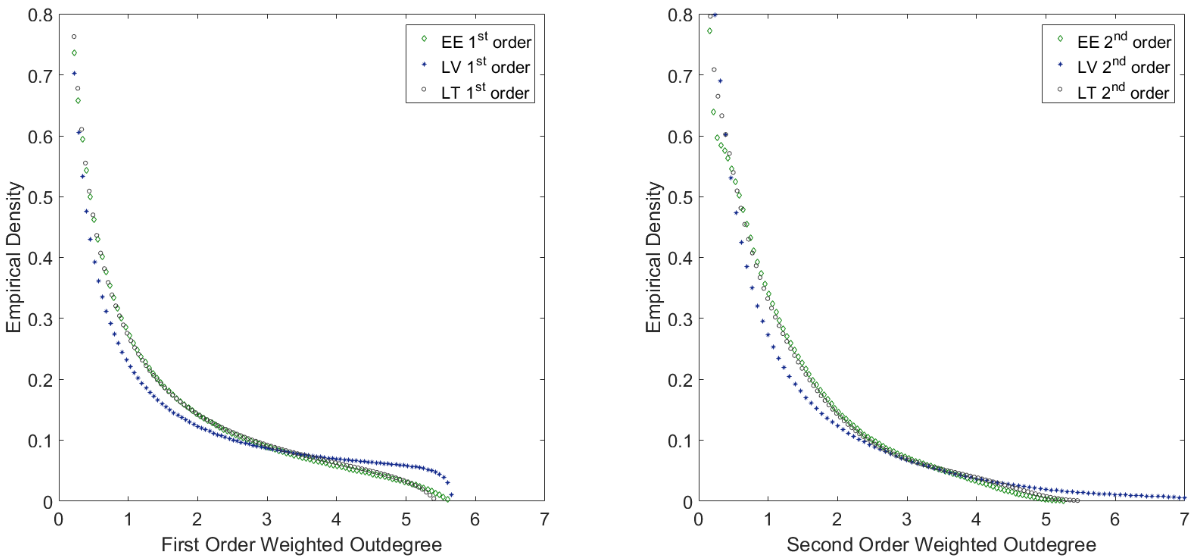

Figure 20. Empirical density of first- and second- order outdegrees in Estonia, Latvia and Lithuania. Source: Eurostat data, own calculations.

[29] The input shares should be in fact equal to 1-α and renormalized to meet the conditions of the model equilibrium. At this point of the analysis however, this plays minor role and neither add nor take anything from it.

Figure 20 presents nonparametric empirical distributions of sectors' (out)degrees in Estonia, Latvia and Lithuania. First order outdegree is a sum of all input shares of a sector i in the whole economy,

$$o_i^1 = \sum_{j=1}^{n} w_{ij} \tag{2}$$

which gives information about how important a sector is as direct source of input in production of other sectors. High values of outdegrees would suggest a general-purpose sector with many others relying on its output in their production technology.

Second order outdegree captures information about the importance of a sector i as an indirect supplier to all other sectors in the economy.

$$o_i^2 = \sum_{j=1}^{n} o_j^1 w_{ji} \tag{3}$$

In other words, it is a sum of first order outdegrees of sectors using *i*'s output in their production, weighted by the shares of corresponding input.

Figure 20 indicates substantially different distributions of outdegrees compared to indegrees from Figure 19. Strong right skew, visible on both graphs, suggests that in each of the Baltic States there are few sectors with multiple, strong supply relations, but majority of sectors provides much less input to others[30]. The skew seems to be the strongest in Latvia. Such heavy tails indicate a power law structure (or Pareto distribution), implying that micro shocks may significantly contribute to aggregate fluctuations (Gabix 2011, Acemoglu et al. 2012). This is further discussed in the next chapter.

Figure 21 presents degree distributions for the V4 countries. Similar skewness and tail behaviour can be observed. There seem to be some interesting cross-country differences in the degrees' distributions deriving from the heterogeneous structural networks presented before. More thorough analysis (than visual) of the degree behaviour is required to estimate the extend of those differences.

[30] The mean of outdegrees is 1, thanks to normalization procedure mentioned before.

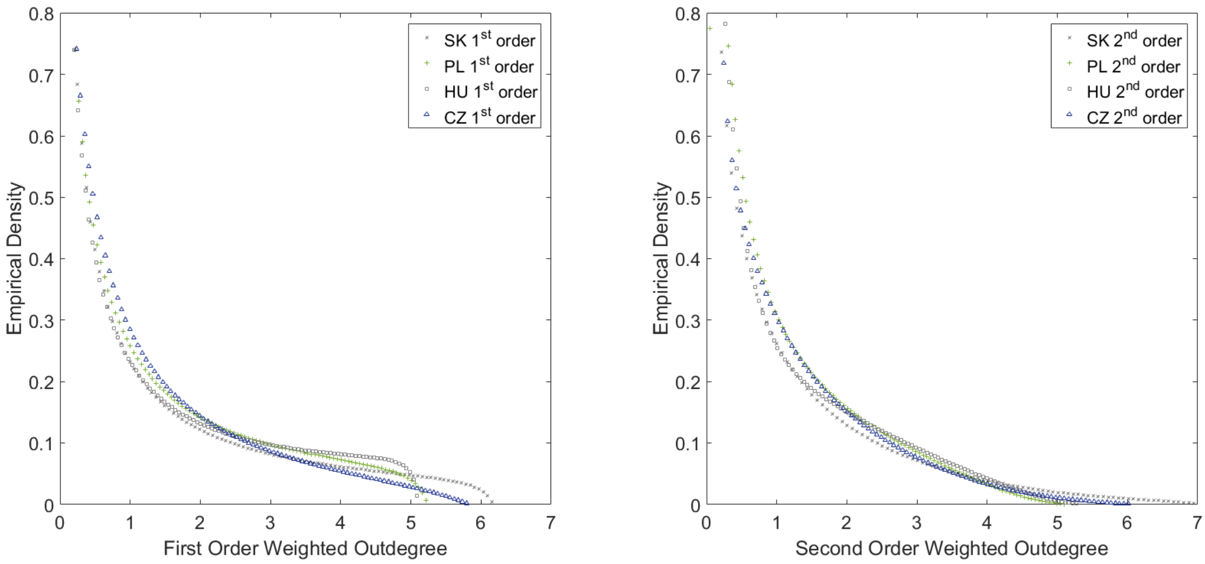

Figure 21. Empirical density of first- and second- order outdegrees in Slovakia, Poland, Hungary and Czech Republic.
Source: Eurostat data, own calculations.

To gain a better perspective about which sectors are the most important direct suppliers in investigated countries and to what extent this output structure overlaps, Table 3 is presented below.

Table 3

Five most important first-order outdegree sectors in CEECs, 2015.

EE		CZ		HU		LT		LV		PL		SK	
45	3,65	**29**	3,85	**45**	3,11	**45**	3,45	**34**	3,67	**27**	3,24	**24**	4,18
46	3,14	**45**	2,56	**11**	2,72	**29**	3,25	**24**	3,42	**31**	2,89	**29**	2,84
34	2,75	**34**	2,42	**46**	2,51	**11**	3,02	**45**	3,37	**29**	2,37	**31**	2,65
11	2,64	**41**	2,22	**17**	2,26	**24**	2,71	**29**	2,87	**24**	2,33	**27**	2,45
24	2,63	**27**	2,13	**24**	2,23	**31**	2,43	**27**	2,49	**11**	2,33	**46**	2,26

Note: Sector numbers in bold.
Source: Eurostat data, own calculations.

Table 3 exhibits the top 5 sectors (in bold) with corresponding outdegree value for seven CEECs. In Estonia, a clear leader as a source of direct input to other sectors in number 45 – *Real Estate services,* followed by *Legal, accounting, management consultancy services*

(46) and *Warehousing and supporting services for transportation* (34). It is apparent that the structure varies between analysed countries. Estonian output share leader occupies first position also in Hungary and Latvia. However, in other countries, a range of different sectors dominate in the ranking; *Wholesale services* (29) in Czech Republic, *Construction* (27) in Poland and *Electricity and gas* (24) in Slovakia. The very bottom of the outdegree ranking is less interesting from the perspective of this essay because of a minor role those sectors can play in shock transmission. Typically, in CEECs the smallest outdegree display sectors relating to sport, creative arts or residential care.[31]

Perhaps the most important measure from the perspective of sectoral network properties and its ability to propagate idiosyncratic shocks is centrality. It accounts for first- as well as higher-order outdegrees and allows to summarize the potential impact of one vertex to the whole interconnected structure. The centrality was introduced to social sciences by Cook et al. (1983), but the generalized concept, used in many seemingly unrelated fields[32], was popularized by Phillip Bonacich (1987) and therefore is often called Bonacich Centrality vector.

$$\boldsymbol{c} = \alpha(I - \beta M)^{-1} M \mathbf{1} \tag{4}$$

where

α – baseline level of centrality

β – propagation parameter

I – identity matrix

M – matrix of relationships in network (adjacency matrix)

1 – column vector of 1s

In the subject of this study, Bonacich centrality closely corresponds to the influence vector (Acemoglu et al. 2012), which has a key role in measuring the shock transmission properties of an economy. Additionally, the formula resembles Leontief inverse. This is an accurate comparison, given that Leontief inverse measures output of a sector to its direct transaction partner and further to all of the partners of the direct input receiver (and so on). The same information should be captured the influence vector, therefore it incorporates Leontief inverse in the formula.

[31] Usually near bottom one can find also *Scientific research and development services* sector, which may be an indicator of how technology-intensive is the manufacturing output of those economies. This investigation is however out of the scope here.

[32] Including for instance webpages ranking algorithm employed by internet browsers.

Table 4

Ranking of top 10 sectors with highest Bonacich centrality scores and position of those sector in supplementary Outdegree, Authority and Hub rankings, Estonia 2015.

Sector	Centrality	Outdegree	Authority	Hub
Real estate services	1	1	16	1
Legal and accounting services; services of head offices; management consultancy services	2	2	30	2
Electricity, gas, steam and air conditioning	3	5	54	3
Warehousing and support services for transportation	4	3	49	4
Wholesale trade services, except of motor vehicles and motorcycles	5	7	5	8
Land transport services and transport services via pipelines	6	6	26	7
Mining and quarrying	7	22	12	20
Coke and refined petroleum products	8	17	23	11
Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services	9	12	11	10
Financial services, except insurance and pension funding	10	9	28	6

Source: Eurostat data, own calculations.

Table 4 contains overview of the sectors in Estonian economy with the highest Bonacich centrality scores[33]. Additionally, three more columns are included, displaying the position of a given sector in a ranking of three different measures: Outdegrees (discussed previously), Authority and Hub. The two latter are supplementary statistics proposed by Kleinberg (1999) and, in his work, were designed to extract information about pages in the WWW networked environment. In the context of a 'web' consisting of sectors and transactions, Authority and Hub measures are derived from eigenvector of an Input-Output matrix and give perspective correspondingly on downstream ranking (how many sectors, especially hubs, are

[33] For clarity, only one country table is presented in the main section of the paper. Corresponding tables for each of the investigated CEECs can be found in the Appendix.

suppliers to this sector) and on upstream ranking (those with most connections to authoritative sectors and other hubs).

Table 4 (along with Tables 8A - 13A in the Appendix) conclude investigation of intersectoral network properties of Visegrád and Baltic economies in 2015. It seems that majority of most central sectors are service related, although strong position of energy industry is noteworthy. The table also allows to get better intuition of a relationships between different measures of importance of vertices. Clearly, centrality scores, outdegrees and hub properties are related, however not equivalent. Even though outdegrees ranking places *Electricity, gas, steam and air conditioning* on 5th place, centrality score suggests even higher importance of this sector. This is because the sector is an important higher-order supplier to the whole economy. Even more meaningful example is *Mining and quarrying* sector, placed in the middle of a pack in terms of direct input-output relations, however playing crucial role in Estonia's value chains by being vital supplier to other key, upstream sectors (hubs). Authority scores seem uncorrelated with other statistics, which is not a surprise. Intuitively it is not expected that every sector, which products are important input to others, have a highly diversified input demand itself.

3.3. CEECs intersectoral networks against other EU countries

The last subsection of this chapter aims to elaborate on a position of Central European and East European Countries' intersectoral networks structure, especially central hubs characteristics, against other, older and economically more advanced European Union members.

Comparing results derived from Input-Output matrices and network architecture graphs of seven developed countries: Austria, Belgium, Germany, Spain, France, Portugal and UK[34], and seven CEECs starts with a general observation. All countries are quite similar in terms of detailed network architecture at this level of disaggregation. Well interconnected networks with some central hubs and some periphery sectors, yet still decently connected with the rest of the economy. General graphs present more divergent architecture, with some distinctive features for each economy. However, looking closely at what sectors are central in those networks, another observation appears. Developed EU countries have more homogenous, services-dominated central hubs. For ten sectors with the highest centrality scores, on average 1,28 is

[34] Since the input-output analysis concerns 2015, a year before the Brexit referendum, United Kingdom is considered an EU member in this paper.

not services-related in the old EU members. CEECs present more heterogeneous arrays of sectors with highest centrality scores. Aside Estonia, in each of those countries five or more sectors among top ten are not services. Estonian network architecture can be considered middle ground with 3 out of 10 top central hubs being not services-related.

There are other features appearing typical for CEECs, such as persistent high position of *Electricity, gas, steam and air conditioning* sector, or importance of *Land transport services and transport via pipelines services* sector in each former Soviet Union country. On the other hand, in the advanced EU economies *Legal and accounting services; services of head offices; management consultancy services* sector is persistently one of the most interconnected sectors (The only country where it is not among the top two in terms of centrality is Spain). Other interesting observations stemming from intersectoral networks analysis are:

A. Computer programming activities is among the most densely interconnected sectors in the UK (3rd place out of 63)
B. There are almost identical patterns of top vertices centralities in Germany and Austria (same top five sectors in the identical order)
C. The general graphs have visibly more structures and single-out sectors apart from the main network structure, compared to CEECs' graphs. In the same time, the main structures are clearer (less dense areas). This suggests that there are fewer strong dependencies in production technologies. This aspect deserves deeper analysis before the verdict on the cause (possible future research avenue).

To summarise this subsection and the whole chapter, several conclusions can be formulated. FSU countries 2015 Input-Output matrices reveal many characteristics of how sectors interact with each other and what are the positions of those sectors in the complete network of the economy. This final shape is a result of post-transition emerging private sector, market forces affecting inherited institutions and production chains fragments, inward FDI and the external setting, with EU policies and funding playing important role.

On average, just over half of each sector input requirements for production comes from output of other sectors. However, the output suppliers are much more divergent. In each country, there are couple of sectors whose output is very important as a production mean to numerous other sectors, whereas most sectors are more final consumer oriented. This observation, along with some particular structures observed in the graphs, indicates that mechanisms transmitting idiosyncratic shocks and contributing to aggregate volatility are present in CEECs economies. Moreover, other countries display similarly complex structures.

Yet, some distinctive observations can be made, namely the homogeneity of seven advanced EU countries and heterogeneity between CEECs. It is not clear yet to what extent those propagation mechanisms add up and how sensitive are the economies compared to each other and developed EU countries. The analysis in the last, fourth chapter should help to answer those puzzles.

4. Impact of Intersectoral Structure on Aggregate Volatility

4.1. Economic model

The analysis of a potential impact of sectors on aggregate fluctuations has to start with the baseline economic model. This essay follows a general equilibrium model of multisectoral economy (static version) proposed in Long, Plosser (1983) and adopted by Acemoglu et al. (2012). Carvalho and Tahbaz-Salehi (2019) further explored possible model extensions and interpretations.

The competitive economy consists of *n* sectors, producing goods for final consumption or to be use as means of production by other sectors. The production technology is a Cobb-Douglas function with CRS[35] assumption. Total output (production) of sector *i* is determined as follows:

$$y_i = (z_i \ell_i)^\alpha \prod_{j=1}^{n} x_{ij}^{(1-\alpha)w_{ij}} \tag{5}$$

where

z_i – idiosyncratic shock

ℓ_i – labour

$\alpha \in (0,1)$ – labour share

x_{ij} – input from sector *j* in production technology

$w_{ij} \in [0,1]$ – proportion of goods produced by sector *j* as a direct production requirement of sector *i*

[35]Constant Return to Scale – Acemoglu, Ozdaglar, Tahbaz-Salehi (2010) show, that the assumption can be relax without meaningful implications for the equilibrium

The input requirement, w_{ij}, corresponds to the entry in Input-Output matrix W. Moreover, $\sum_{j=1}^{n} w_{ij} = 1$ for all sector. If $w_{ij} = 0$, it means that the sector i is independent from j in terms of production. It is possible, that a sector would not need any external input (as in the example of horizontal economy structure). In that case, w_{ii} is equal to one and all other elements of i^{th} row in W matrix are zeros. Additionally, a clear labour market assumption is in force ($\sum_{i=1}^{n} \ell_i = 1$).

The final goods' consumers are households, endowed with a unit of labour and Cobb-Douglas preferences when deciding on the consumption proportions of *n* different goods:

$$u(c_1, \dots, c_n) = \gamma \prod_{i=1}^{n} (c_i)^{\frac{1}{n}} \tag{6}$$

where
c_i – consumption of sector *i* commodity
γ – normalization constant

Similarly, to labour market, the product markets clear, meaning that all the goods produced by every sector are either consumed by household or used as an input by other sector (that is $c_i + \sum_{j=1}^{n} x_{ji} = y_i$).

Acemoglu et al. (2012) show, that competitive equilibrium in such economy implicates that logarithm of wages is equal to linear combination of *influence vector* and a set of shock, which can be interpreted as:

$$\log(GDP) = \nu' \varepsilon \tag{7}$$

where
$\nu \equiv \frac{\alpha}{n}[I - (1-\alpha)W']^{-1}\mathbf{1}$ is a normalized[36] influence vector of *n* dimensions
$\varepsilon \equiv [\log(z_1), \dots, \log(z_n)]'$ is a normalized vector of sectoral shocks' distributions

[36] Normalization affects only mean, the volatility and distribution properties remain unchanged and allow to carry on with the analysis.

This summarizes the most important take from the microeconomic set-up. The aggregate output is proportional to shocks and corresponding coefficients from the *influence vector*. It is apparent that the latter vector is strictly related to the intersectoral network properties of the economy, namely Bonacich centrality scores of vertices. The vector incorporates Input-Output matrix through a normalized Leontief Inverse.

4.2. Transmission mechanisms

Perhaps the biggest contribution of Acemoglu at al. (2012) is recognition of the nature of relation between the network-specific set of degrees and the volatility of the output in aforementioned equilibrium. In essence, they show that the bigger is the disparity between degrees, the higher volatility we can expect. To get a better intuition of the dependency, some key formulas are presented in this subsection.

Assessing the impact of direct shocks starts with defining the coefficient of variation (CV) and showing how aggregate volatility (AV) is bound to it:

$$CV \equiv \frac{1}{\overline{o^1}}\left[\frac{1}{n-1}\sum_{i=1}^{n}\left(o_i^1 - \overline{o^1}\right)^2\right]^{\frac{1}{2}} \tag{8}$$

where

$\overline{o^1}$ – average first-order degree

$$AV = \Omega\left(\frac{1+CV}{\sqrt{n}}\right) \tag{9}$$

Aggregate volatility is understood here as aggregate output's standard deviation. The notion Ω indicates, that in increasingly disaggregated economy, the volatility cannot decay faster than $\frac{1}{\sqrt{n}}$ as implied by the law of large numbers[37]. Above equations demonstrate that if few sectors are considerably more important direct suppliers than the rest of the economy (meaning, they have much higher outdegrees), coefficient of variation is bigger. This imply, that production shocks to those sectors will affect the total production in the economy and contribute to

[37] Formally the expression states that $\lim_{n\to\infty} \frac{AV}{\frac{1+CV}{\sqrt{n}}} > 0$

aggregate volatility's significantly slower decay than the pace characteristic for horizontal or perfectly interconnected economy (diversification argument).

Subsequently, authors prove that if the empirical distribution of degrees can be approximated by Pareto distribution (the tail is heavy enough to have a power law structure), then:

$$AV = \Omega\left(n^{-\frac{\eta-1}{\eta}-\eta}\right) \tag{10}$$

where
η – shape parameter $\in (1,2)$
δ is arbitrary and > 0

Low values of the shape parameter indicate more heterogeneous outdegree structure and, consequently, bigger aggregate fluctuations. However, even if shape parameter is above 2 it is still possible that other kind of mechanism prevents fluctuation to decay in the rate of $\sqrt{n}$.

To account for possible indirect shock propagation mechanism trough the cascade effects, the interconnectivity coefficient τ is specified as follows:

$$\tau(W) \equiv \sum_{i=1}^{n}\sum_{j\neq i}\sum_{k\neq i,j} w_{ji}w_{ki}o_j^1 o_k^i \tag{11}$$

τ coefficient has higher values if in the sectoral network sectors with high outdegrees are connected by a common supplier with other sectors with high outdegrees. This captures situations such as infamous Ford and GM plea for a bailout to the US government in 2008, when financial problems of Chrysler could ruin some of its suppliers, and because of an overlap in supply chains, this would also pose serious threat to the main competitors (The Economist 2008). Following τ definition, the aggregate volatility equation can be augmented to:

$$AV = \Omega\left(\frac{1}{\sqrt{n}} + \frac{CV}{\sqrt{n}} + \frac{\sqrt{\tau(W)}}{n}\right) \tag{12}$$

And consequently, if the second-order degrees display sufficiently heavy tail suggesting Pareto distribution, then:

$$AV = \Omega\left(n^{-\frac{\zeta-1}{\zeta}-\delta}\right) \tag{13}$$

where

ζ – second-order shape parameter $\in (1,2)$

δ is arbitrary and > 0

4.3. Empirical results

It has been established that high divergence between first- and higher-order outdegrees in the intersectoral network structure may contribute significantly to aggregate output volatility. Especially, if the distribution of the outdegree resembles Pareto distribution, the shocks will propagate throughout the economy instead of vanish according to the Central Limit Theorem. In subsection 3.4. the outdegree distributions were examined – both displayed a strong right skew and heavy tail, especially the second-order outdegree distributions. To quantify these observations, a regression can be employed to estimate the shape parameters of the distribution's tails. Following Gabaix and Ibragimov (2011) proposition to avoid a small sample bias, the OLS log *Rank-1/2*-log regression is used for shape parameter predictions.

Table 5

Estimates of the outdegrees shape parameters (modified OLS) for 7 CEECs.

	EE	CZ	HU	LT	LV	PL	SK
$\hat{\eta}$	1,95	1,96	1,52	1,76	1,56	1,80	1,68
	(0,42)	(0,42)	(0,33)	(0,38)	(0,33)	(0,39)	(0,36)
$\hat{\zeta}$	1,44	1,38	1,10	1,34	1,13	1,27	1,22
	(0,31)	(0,30)	(0,23)	(0,29)	(0,24)	(0,27)	(0,26)
n	63	61	63	62	63	61	62

Note: $\hat{\eta}$ and $\hat{\zeta}$ refer to estimated first- and second-order outdegree distribution shape parameters respectively. Brackets contain corresponding standard errors. *n* is a number of sectors in each country network. 70% of the sample is used to estimate the tail parameters. Source: Eurostat data, own calculations.

Table 5 displays results of the regression for the seven Central and East European Countries. $\hat{\eta}$ = 1,95 in case of Estonia and $\hat{\eta}$ = 1,96 in Czech Republic suggest, that those countries are not affected by the effects of direct idiosyncratic shocks transmission to a great extent. The value close to 2,00 hints that the tempo of volatility decay from this kind of shock is close to the rate associated with standard diversification argument. On the other hand, $\hat{\zeta}$ between 1,10 and 1,44 indicates, that indirect shock transmission plays much more important role in the aggregate output behaviour. In Estonia, this result implies that the volatility should not decay faster than $n^{\frac{1,44-1}{1,44}} = n^{0,31}$, which is significantly slower than $\sqrt{n}$.

Table 5 allows to compare the results of shock-transmission properties between seven transition countries. The differences are substantial, with three distinguishable subgroups. Estonia and Czech Republic intersectoral networks seem to be the most resistant to shock transmission mechanisms. Interestingly, even though Czech Republic has marginally more robust score in terms of first-order degrees, overall all it is the Estonia with the most impervious intersectoral architecture (lower bound $\hat{\zeta}$ is notably higher). Middle pack consists of Lithuania, Poland and Slovakia, whereas the most vulnerable networks are those of Hungary and Latvia.

Summing up, the results are quite surprising. There are sizable differences between CEE countries and no clear pattern in the top-to-bottom arrangement. Noteworthy divergence between Baltic States is particularly striking. In contrast, seven old EU members display much more homogeneous picture in terms of outdegree tail distributions[38], with average $\hat{\eta}$ = 1,80 and average $\hat{\zeta}$ = 1,38. While Estonia and Czech Republic have one of the best scores along UK when comparing all fourteen countries, Latvia and Hungary perform much worse than any other country. The additional Table 14A with results for other EU countries is available in the Appendix.

Conclusion

The study of countries' intersectoral networks requires combining input-output analysis, network research methodological framework, microeconomic modelling, and business cycles literature findings to conclude one macro feature of an economy. The study area is at the early development stage; however, it seems to be a promising field given the new insight it gives to a macroeconomic risk assessment. This essay aimed to contribute to the field by incorporating this emerging approach to examine the intersectoral structure of seven transition countries, four Visegrád Group members and three Baltic States. Furthermore, the

[38] Average absolute deviation from the mean for $\hat{\eta}$ and $\hat{\zeta}$ is equal respectively 0,14 and 0,10 for NMS and 0,08 and 0,06 for Old EU.

paper evaluated the risk of idiosyncratic shock transmissions within the countries multisectoral network and compared it with other older EU members.

The findings indicate that the sectoral structures of the seven transition economies are significantly heterogeneous. The most central hubs distributions are also divergent between FSU countries and to a greater extent than in older EU members. Among most interconnected vertices, service-related sectors dominate only in Estonia, which is unusual compared to other CEECs. However, older EU members have heavily services-centred economies, which suggests that the Estonian structure is converging towards the advanced countries more rapidly than other transition economies in terms of sectoral network architecture.

The outdegree distribution in the V4 and the Baltic States indicate that the mechanisms of idiosyncratic shocks propagation are present in their economy and may contribute to aggregate fluctuations. Particularly important are the cascade effects affecting the economy by the indirect transmission of sectoral shocks. Comparing the results on the country level, it seems that in 2015 Estonia was the most resistant country to shock propagation within CEECs and the second most resistant in the whole sample of 14 EU members (after the UK). Interestingly, CEECs also present more heterogeneous results of outdegree distributions' tail parameters estimation than their western neighbours.

There are several limitations to the study, most of which refer to the data quality. The most important is the disaggregation level of the data. Analysis of the empirical tails of the distributions resembling Pareto could be more insightful with a bigger sample. Moreover, in order to introduce tailored policies aimed at protecting the economy against transmitted micro shocks, more precise identification of the most vulnerable supply chain links is necessary. More disaggregated data is, in fact, available for national statistics offices; however, the statistical secret may play an important role in publishing such data, especially in smaller countries, where a subsector may consist of only a few firms. Another potential, data-related fragility of the robustness of the study comes from the fact that some inconsistencies were found even in the most homogenous database from Eurostat, where the global procedures should have been strictly scrutinized. There may be more unidentified differences between countries related to data compilation, affecting the results of comparative analysis. Another limitation is not accounting for upstream shocks (the effects of price and quantity cancel out under Cobb-Douglas technology assumption). Acemoglu, Akcigit and Kerr (2016) demonstrate an example of how such shocks could propagate. Expending the model to account for this kind of shocks could shed more light on the production interdependencies in the studied countries.

Avenue worth investigating in future works is a more endogenous approach to the input-output relations between sectors in CEE. Presented considerations about network structure determinants in transition economies are only a broad illustration of probable macro-origins. Such discussion may hold value on the broad scope of high sectoral aggregation level (like presented in the paper), but the micro-origin of interconnectedness needs a better methodological tool. A better explanation of why disaggregated sectors (and firms) decide to connect with a particular partner would allow a greater understanding of the limitations of the shock transmissions mechanisms (maybe are we doomed to cascade effects no matter what?) and could be a valuable contribution, especially for policymakers in transition countries aiming at fostering economic resilience. Lastly, yet another way forward would be to add the time dimension to the analysis in an attempt to capture better the dynamics of intersectoral network shaping of the countries.

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Appendix

Table 6A
Names of the sectors used in Input Output Tables

No	CPA class	Name
1	CPA_A01	Products of agriculture, hunting and related services
2	CPA_A02	Products of forestry, logging and related services
3	CPA_A03	Fish and other fishing products; aquaculture products; support services to fishing
4	CPA_B	Mining and quarrying
5	CPA_C10-12	Food, beverages and tobacco products
6	CPA_C13-15	Textiles, wearing apparel, leather and related products
7	CPA_C16	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials
8	CPA_C17	Paper and paper products
9	CPA_C18	Printing and recording services
10	CPA_C19	Coke and refined petroleum products
11	CPA_C20	Chemicals and chemical products
12	CPA_C21	Basic pharmaceutical products and pharmaceutical preparations
13	CPA_C22	Rubber and plastic products
14	CPA_C23	Other non-metallic mineral products
15	CPA_C24	Basic metals
16	CPA_C25	Fabricated metal products, except machinery and equipment
17	CPA_C26	Computer, electronic and optical products
18	CPA_C27	Electrical equipment
19	CPA_C28	Machinery and equipment n.e.c.
20	CPA_C29	Motor vehicles, trailers and semi-trailers
21	CPA_C30	Other transport equipment
22	CPA_C31_32	Furniture and other manufactured goods
23	CPA_C33	Repair and installation services of machinery and equipment
24	CPA_D	Electricity, gas, steam and air conditioning
25	CPA_E36	Natural water; water treatment and supply services
26	CPA_E37-39	Sewerage services; sewage sludge; waste collection, treatment and disposal services; materials recovery services; remediation services and other wa...
27	CPA_F	Constructions and construction works
28	CPA_G45	Wholesale and retail trade and repair services of motor vehicles and motorcycles
29	CPA_G46	Wholesale trade services, except of motor vehicles and motorcycles
30	CPA_G47	Retail trade services, except of motor vehicles and motorcycles
31	CPA_H49	Land transport services and transport services via pipelines
32	CPA_H50	Water transport services
33	CPA_H51	Air transport services
34	CPA_H52	Warehousing and support services for transportation
35	CPA_H53	Postal and courier services

36	CPA_I	Accommodation and food services
37	CPA_J58	Publishing services
38	CPA_J59_60	Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services
39	CPA_J61	Telecommunications services
40	CPA_J62_63	Computer programming, consultancy and related services; Information services
41	CPA_K64	Financial services, except insurance and pension funding
42	CPA_K65	Insurance, reinsurance and pension funding services, except compulsory social security
43	CPA_K66	Services auxiliary to financial services and insurance services
44	CPA_L68B	Imputed rents of owner-occupied dwellings
45	CPA_L68A	Real estate services excluding imputed rents
46	CPA_M69_70	Legal and accounting services; services of head offices; management consultancy services
47	CPA_M71	Architectural and engineering services; technical testing and analysis services
48	CPA_M72	Scientific research and development services
49	CPA_M73	Advertising and market research services
50	CPA_M74_75	Other professional, scientific and technical services and veterinary services
51	CPA_N77	Rental and leasing services
52	CPA_N78	Employment services
53	CPA_N79	Travel agency, tour operator and other reservation services and related services
54	CPA_N80-82	Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services
55	CPA_O	Public administration and defence services; compulsory social security services
56	CPA_P	Education services
57	CPA_Q86	Human health services
58	CPA_Q87_88	Residential care services; social work services without accommodation
59	CPA_R90-92	Creative, arts, entertainment, library, archive, museum, other cultural services; gambling and betting services
60	CPA_R93	Sporting services and amusement and recreation services
61	CPA_S94	Services furnished by membership organisations
62	CPA_S95	Repair services of computers and personal and household goods
63	CPA_S96	Other personal services

Source: Eurostat

Table 7A displays all corrections which were performed to obtained the IO matrices of the highest possible quality. It resulted in slightly varying number of sectors among CEECs in the analysis, how it should not have significant impact on the results.

Table 7A

Data notes – all found database inconsistencies in Eurostat and national sources

EE	Eurostat data for EUR currency display slightly different values than National Currency. The latter corresponds to tables published by Statistics Estonia and therefore it is used in the analysis.
CZ	Retail sectors for motor vehicles is merged with Retail except motor vehicles. Real estate services sector is merged with imputed rents. Therefore, final IO matrix is smaller by 2 branches (n=61)
PL	Transport services (H50-H53) where marked as confidential in Eurostat tables. However, national sources provide information for those sectors, aggregated in pairs: Water and Air transport services together and Warehousing and Postal services together. The decision was made to include those sectors in the IO matrix and therefore n=61 (instead of n=59 if keeping confidentiality marker)
SK	Real Estate and Imputed rents merged together (n=62)
LT	Coke and refined petroleum products and Chemicals and chemical products sectors merged together in original source data, and marked confidential in Eurostat data. Similar procedure to PL case was applied, leaving n=62 in final IO matrix.

Source: Own comparison (and resulting calculations) based on Eurostat and national sources of corresponding countries databases.

Table 8A

Ranking of top 10 sectors with highest Bonacich centrality scores and position of those sector in supplementary Outdegree, Authority and Hub rankings, Latvia 2015.

Sector	Centrality	Outdegree	Authority	Hub
Wholesale trade services, except of motor vehicles and motorcycles	1	4	7	5
Warehousing and support services for transportation	2	1	62	1
Real estate services excluding imputed rents	3	3	25	2
Electricity, gas, steam and air conditioning	4	2	60	3
Land transport services and transport services via pipelines	5	10	14	8
Coke and refined petroleum products	6	17	5	14

Constructions and construction works	7	5	53	4
Fabricated metal products, except machinery and equipment	8	15	29	13
Chemicals and chemical products	9	11	37	9

Source: Eurostat data, own calculations.

Table 9A

Ranking of top 10 sectors with highest Bonacich centrality scores and position of those sector in supplementary Outdegree, Authority and Hub rankings, Lithuania 2015.

Sector	Centrality	Outdegree	Authority	Hub
Wholesale trade services, except of motor vehicles and motorcycles	1	2	23	3
Real estate services excluding imputed rents	2	1	43	1
Electricity, gas, steam and air conditioning	3	4	46	4
Land transport services and transport services via pipelines	4	5	57	5
Coke and refined petroleum products + Chemicals and chemical products	5	3	61	2
Constructions and construction works	6	7	29	8
Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services	7	10	30	9
Legal and accounting services; services of head offices; management consultancy services	8	6	49	7
Mining and quarrying	9	23	18	23

Source: Eurostat data, own calculations.

Table 10A

Ranking of top 10 sectors with highest Bonacich centrality scores and position of those sector in supplementary Outdegree, Authority and Hub rankings, Czech Republic 2015.

Sector	Centrality	Outdegree	Authority	Hub
Wholesale trade services, except of motor vehicles and motorcycles	1	1	32	1
Mining and quarrying	2	9	8	2
Real estate services and imputed rents	3	2	23	4
Coke and refined petroleum products	4	26	1	13
Warehousing and support services for transportation	5	3	48	3
Land transport services and transport services via pipelines	6	17	5	12
Electricity, gas, steam and air conditioning	7	7	9	7
Machinery and equipment n.e.c.	8	15	11	10
Financial services, except insurance and pension funding	9	4	46	5

Source: Eurostat data, own calculations.

Table 11A

Ranking of top 10 sectors with highest Bonacich centrality scores and position of those sector in supplementary Outdegree, Authority and Hub rankings, Hungary 2015.

Sector	Centrality	Outdegree	Authority	Hub
Real estate services excluding imputed rents	1	1	17	1
Coke and refined petroleum products	2	11	1	8
Legal and accounting services; services of head offices; management consultancy services	3	3	33	2
Mining and quarrying	4	8	43	6
Chemicals and chemical products	5	2	46	3
Electricity, gas, steam and air conditioning	6	5	19	4
Land transport services and transport services via pipelines	7	10	20	9

Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services	8	7	26	5
Wholesale trade services, except of motor vehicles and motorcycles	9	6	22	7

Source: Eurostat data, own calculations.

Table 12A

Ranking of top 10 sectors with highest Bonacich centrality scores and position of those sector in supplementary Outdegree, Authority and Hub rankings, Poland 2015.

Sector	Centrality	Outdegree	Authority	Hub
Constructions and construction works	1	1	53	1
Land transport services and transport services via pipelines	2	2	45	2
Electricity, gas, steam and air conditioning	3	4	3	3
Mining and quarrying	4	10	26	4
Wholesale trade services, except of motor vehicles and motorcycles	5	3	11	5
Real estate services excluding imputed rents	6	12	6	9
Coke and refined petroleum products	7	24	5	19
Warehousing and support services for transportation + Postal and courier services	8	14	7	12
Legal and accounting services; services of head offices; management consultancy services	9	6	50	8

Source: Eurostat data, own calculations.

Table 13A

Ranking of top 10 sectors with highest Bonacich centrality scores and position of those sector in supplementary Outdegree, Authority and Hub rankings, Slovakia 2015.

Sector	Centrality	Outdegree	Authority	Hub
Electricity, gas, steam and air conditioning	1	1	52	1
Mining and quarrying	2	8	6	3
Wholesale trade services, except of motor vehicles and motorcycles	3	2	34	2
Land transport services and transport services via pipelines	4	3	42	4
Coke and refined petroleum products	5	28	2	21
Chemicals and chemical products	6	6	23	7
Real estate services excluding imputed rents	7	9	17	8
Legal and accounting services; services of head offices; management consultancy services	8	5	47	6
Warehousing and support services for transportation	9	14	22	11

Source: Eurostat data, own calculations.

Table 14A

Estimates of the outdegrees shape parameters (modified OLS) for 7 old EU member states.

	AT	BE	DE	ES	FR	PT	UK
β hat	1,76	1,75	1,87	1,72	1,67	1,85	1,96
	(0,38)	(0,37)	(0,40)	(0,37)	(0,36)	(0,39)	(0,42)
ζ hat	1,37	1,26	1,42	1,38	1,27	1,38	1,56
	(0,29)	(0,27)	(0,30)	(0,29)	(0,27)	(0,29)	(0,33)
n	63	63	63	63	63	63	63

Source: Eurostat data, own calculations

Figures 22A-28A illustrate additional outlook on power law behaviour of outdegrees distributions' tails in transition countries by plotting CDDF[39] functions (on logarithmic scale). Red line marks the Pareto distribution, which seem to be a good approximation of a nonparametric estimate.

[39] Counter-Cumulative Distribution Function = 1 - CDF

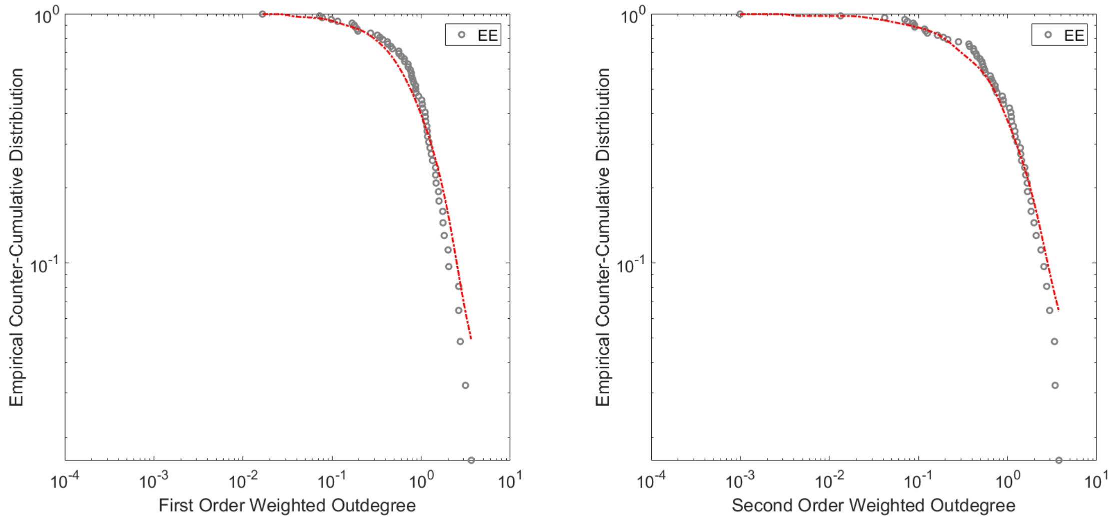

Figure 22A. Empirical CCDFs of first- and second- order outdegrees in Estonia.
Source: Eurostat data, own calculations.

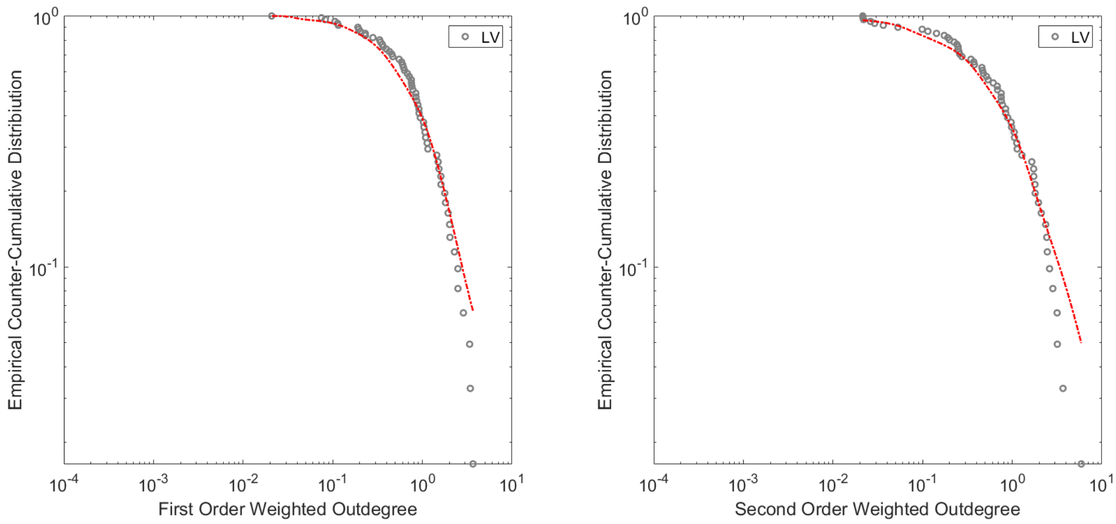

Figure 23A. Empirical CCDFs of first- and second- order outdegrees in Latvia.
Source: Eurostat data, own calculations.

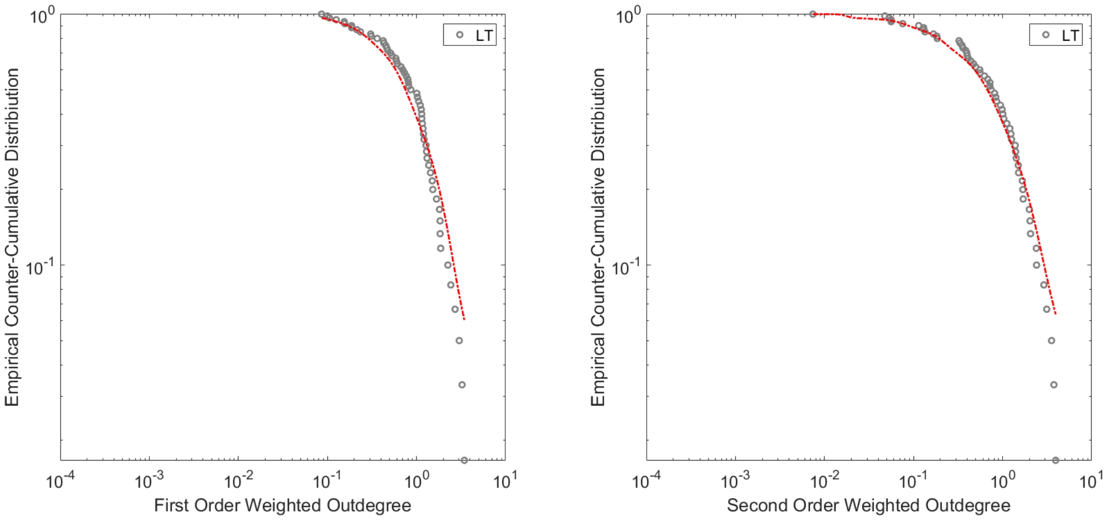

Figure 24A. Empirical CCDFs of first- and second- order outdegrees in Lithuania.
Source: Eurostat data, own calculations.

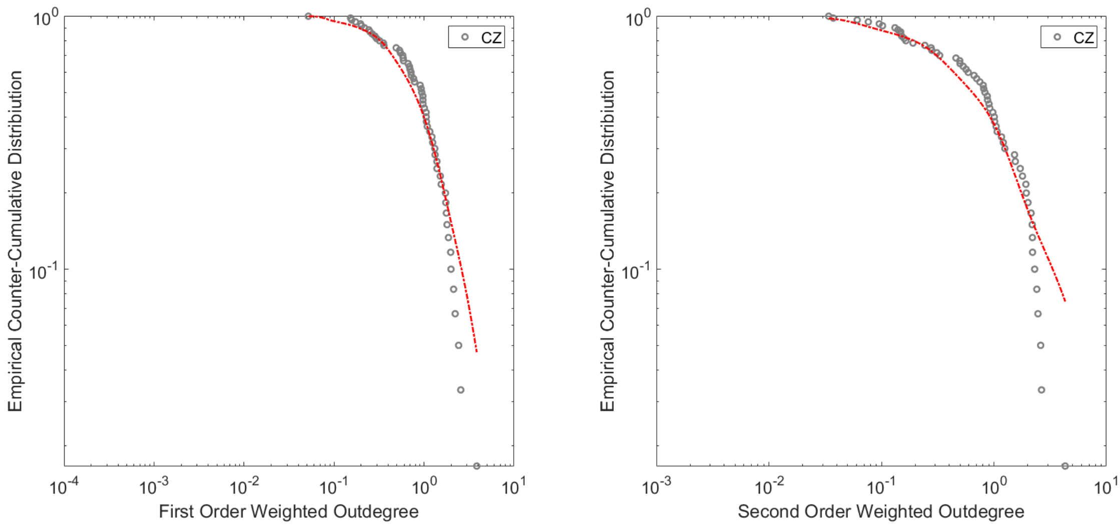

Figure 25A. Empirical CCDFs of first- and second- order outdegrees in Czech Republic.
Source: Eurostat data, own calculations.

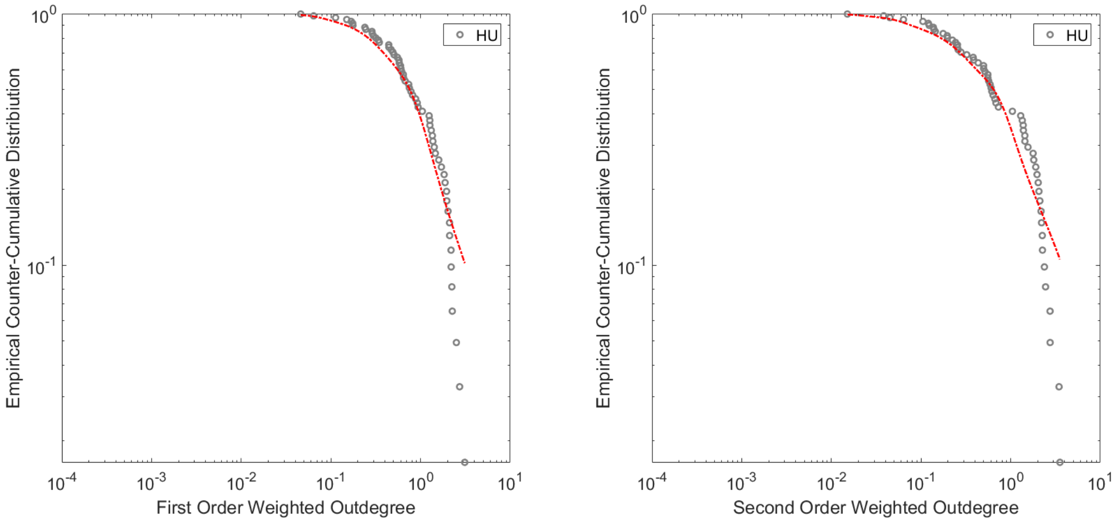

Figure 26A. Empirical CCDFs of first- and second- order outdegrees in Hungary.
Source: Eurostat data, own calculations.

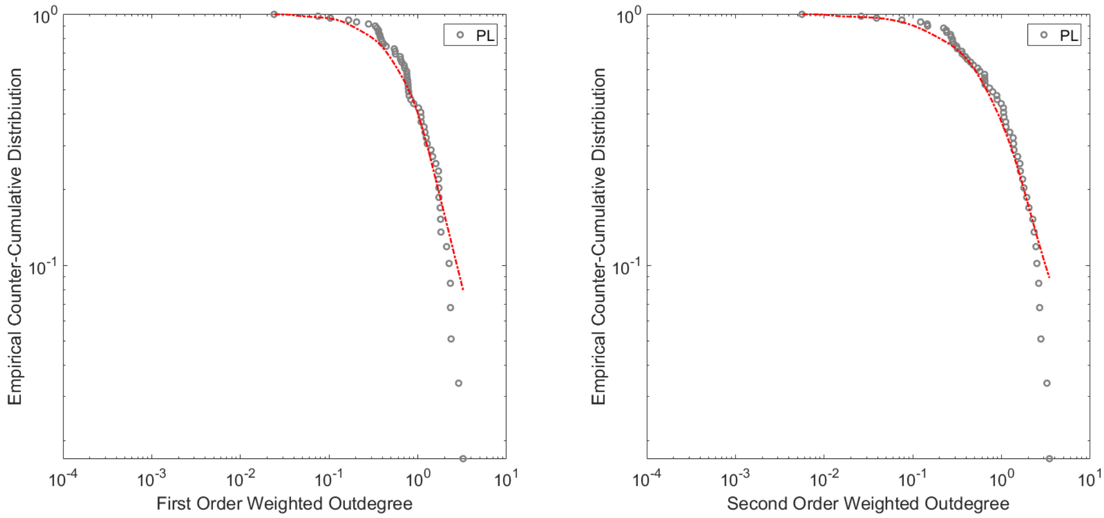

Figure 27A. Empirical CCDFs of first- and second- order outdegrees in Poland.
Source: Eurostat data, own calculations.

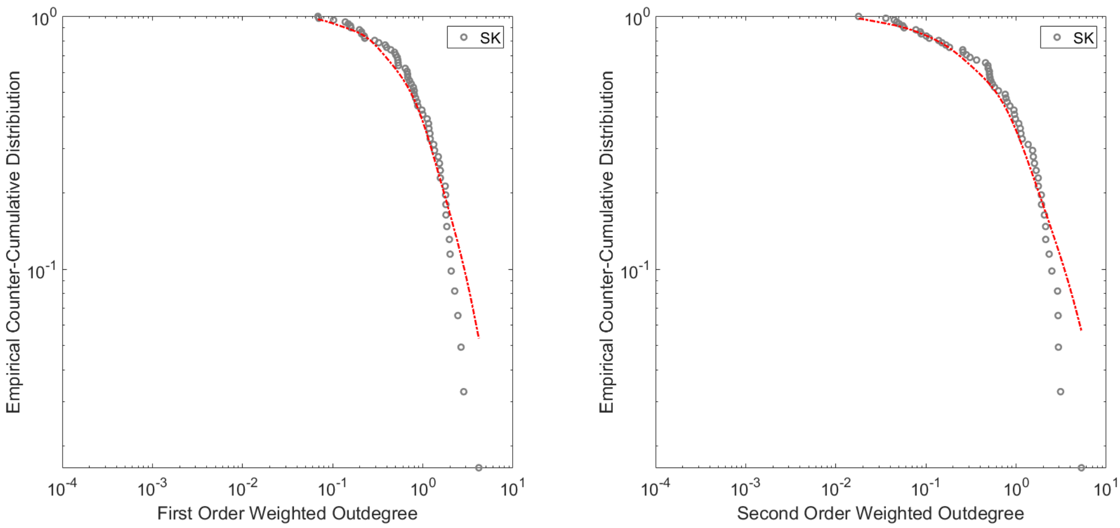

Figure 28A. Empirical CCDFs of first- and second- order outdegrees in Slovakia.
Source: Eurostat data, own calculations.

Resümee

ŠOKKIDE LEVIKUMEHHANISMID MAJANDUSHARUDE VAHELISTES VÕRGUSTIKES KESK- JA IDA-EUROOPA RIIKIDE NÄITEL

Michał Nowak

Käesolev artikkel uurib tootmisseoseid majandussektorite vahel seitsmes üleminekuriigis – neljas Visegrádi ja kolmes Balti riigis. Tootmisseoseid saab väljendada riigipõhiste sisend-väljundmaatriksite abil, mida saab omakorda illustreerida tippude (sektorite) ja servade (nendevaheliste tehingute) võrgustikena. See artikkel uuribki tootmisseoste võrgustike kujunemist ja eripärasid. Empiirilise osa põhieesmärk on hinnata vastava kirjandusvaldkonna vaatenurgast võrgustike omadusi ehk täpsemalt nende asümmeetriat idiosünkraatiliste šokkide levimisel. Analüüsitakse 2015. aasta andmetel 14 riigi maatrikseid, mis hõlmavad kokku üle 50 000 majandusharude vahelise tehingu. Tulemused on järgmised. Kesk- ja Ida-Euroopa riikide majandusharude vahelised võrgustikud on üllatavalt erinevad, keskpunktina toimivad erinevad väärtusahelate osad ning väga erinevad teenuste või ka tööstussektorid. Võrdluseks, arenenud ELi majandused on palju homogeensemad ning seal domineerivad võrgustikustruktuurides kesksena teenuste harud. Empiirilise analüüsi põhjal saab öelda, et võrgustike kaudu toimuvad šokkide levimismehhanismid, eriti kaudsed kaskaadiefektid, võivad mõjutada toodangu agregeeritud volatiilsust kõigis analüüsitud riikides. Mõni üleminekuriik näib analüüsi tulemuste põhjal siiski teistega võrreldes selliste šokkide suhtes vastupidavam (nt Eesti ja Tšehhi Vabariik). Samal ajal on uuritud riikidest just kahe riigi sektoritevahelised võrgustruktuurid šokkide suhtes väga haavatavad (Läti ja Ungari). Käesolev artikkel pakub kokkuvõttes uut, võrdlevat perspektiivi endise Nõukogude Liidu (mõju)alasse jäänud majanduste arenguväljavaadete kohta, lisades majandusliku transformatsiooni alasesse kirjandusse šokkide leviku mikroökonoomilise käsitluse.

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24/05/2021