Society and Economy 45 (2023) 3, 293–312
DOI: 10.1556/204.2023.00010

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Global value chains and knowledge spillover to local economy in Visegrad 4 countries

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Received: October 23, 2022 • Revised manuscript received: May 4, 2023 • Accepted: May 19, 2023
Published online: June 22, 2023

ABSTRACT

This study empirically examines knowledge spillover in Visegrad Four (V4) countries, with an emphasis on global value chains (GVCs). Using patent statistics, the study aims to estimate the knowledge production function, including domestic and foreign knowledge stocks, and found that international knowledge spillover does not contribute much to the innovation of the local economy in the V4 countries because of three factors: i) multinational corporations' (MNCs) strategy to locate a low-cost production base, ii) MNCs' strategy to locate supporting (process, production or non-core product related) research and development (R&D) activities and iii) limited technology spillover effect from MNCs to local firms. Local firms in the V4 countries became dependent on the peripheral products and technologies provided by MNCs, and as a result, local R&D activities in the V4 countries were diverted from patentable innovation.

KEYWORDS

knowledge spillover, innovation, GVCs, V4, Hungary, automotive industry

JEL CLASSIFICATIONS

O32, O33, O52

1. INTRODUCTION

To what extent do global value chains (GVCs) contribute to innovation in the Visegrad Four (V4) countries, that is, Czechia, Slovakia, Hungary and Poland? Do GVCs facilitate the transfer

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of knowledge to local firms in these countries? This paper seeks to answer these questions. The V4 countries experienced radical politico-economic reforms after the collapse of the communist administrations in the late 1980s and early 1990s, and in the transition towards a free market system, high dependence on foreign capital and export-led growth have become major strategies for economic development in the region (Nolke – Vilegenthart 2009; Myant – Drahokoupil 2012). In this context, foreign direct investment (FDI) and production networks created by multinational corporations (MNCs) have been the key drivers of economic transformation and development in V4 countries in the last three decades. Therefore, it is important to explore how GVCs enhance local innovations because GVCs are considered one of the major channels of knowledge spillover. For instance, Ernest and Kim (2002) asserted that global production networks facilitate the transfer of technology and enhance the absorptive capacity of local suppliers. As the theory of endogenous growth indicates, knowledge spillover plays a major role in innovation and technological progress.[1] In contrast, the literature reveals adverse empirical evidence, claiming that integration through such production networks is not perfect and that technology transfer from the most advanced economies to less advanced ones remains limited. For instance, Pavlínek (2018) and Krpec and Hodulák (2019) introduced the concept of the integrated periphery as a transitional phase for countries that are willing to develop their economy based on FDI and accession to GVCs, from a peripheral status towards the core. Instead of the traditional dichotomy of core-periphery status, the authors identified the semi-peripheral and integrated peripheral positions. In their perspective, an integrated peripheral economy is integrated into the GVCs in a dependent, subordinate position where local capabilities and research and development (R&D) spending are even weaker than in the semi-peripheral countries and where the basis of competitiveness lies in their (still) low level of labour cost. This also projects that research and innovation-related activities will be weaker in such countries than in the more advanced core or semi-peripheral countries.

This study aimed to examine the spillover of international knowledge to the local economy in the V4 countries through GVC networks to provide further evidence of their impact on local innovation performance. For this study, both quantitative and qualitative analyses were employed. Econometric analysis was used to examine knowledge spillovers by estimating *knowledge production functions* using patent data. A panel cointegration analysis was applied, using the fully-modified ordinary square (FMOLS) estimator. Furthermore, the automotive industry in Hungary was used as a case study in order to gain more insight into the local impacts of GVCs. A range of secondary sources were employed, including statistical data from the OECD, the European Patent Office (EPO), the World Bank, Eurostat and the Hungarian Central Statistical Office, and interviews with a multinational subsidiary and three local capital firms in Hungary conducted between 2019 and 2020.

The structure of the paper is as follows. Section 2 reviews the literature on GVCs and innovativeness; Section 3 describes the conceptual framework of knowledge spillover and knowledge production function, while Section 4 explains the econometric model and data. Section 5

[1]Knowledge spillover is a positive externality from prior knowledge. Strictly, there should be a difference between intentional technology transfer and spillover. However, as most studies in the literature do not consider the distinction, this paper also considers both intentional and unintentional technology diffusion to be knowledge spillover.

provides the estimation results and discusses the results, and Section 6 presents the case study of Hungary, followed by the conclusion.

2. GVCS AND INNOVATIONS

The GVC concept documents the input-output relation of the chain across countries by analysing successive links of all economic activities from conception to production, distribution and final consumption, with emphasis on five forms of governance structures: market, modular, relational, captive and hierarchy (Gereffi 1999; Gereffi et al. 2005; Fernandez-Stark – Gereffi 2019). More importantly, the theory asserts the industrial upgrading of local industries by identifying four main upgrading dynamics: process upgrading, product upgrading, functional upgrading and intersectional upgrading (Humphrey – Schmitz 2002). Although the GVC theory generally views that GVCs allow local firms in developing countries to achieve industrial upgrading by obtaining higher value-added activities through the chain (OECD 2013; Kaplinsky – Morris 2001), some literature is sceptical about this upgrading process. These studies assert that low-value processes are easily transferrable from lead firms to local firms, while high-value processes are likely to remain in lead firms (Bair – Gereffi 2001; Pavlínek – Ženka 2011; Rugraff 2010; Smith et al. 2014; Tokatli 2013). Hence, based on these processes (or functions) of GVCs, countries might be categorized into core or peripheral countries (as well as into semi-peripheral or integrated peripheral countries; Pavlinek 2018; Krpec – Hodulak 2019).

Regarding technology transfer, the literature on GVCs further examines the innovation systems and technological capabilities of local firms (see Pietrobelli – Rabellotti 2011; Lema et al. 2019; Staritz – Whitfield 2019). More remarkably, Durant and Milberg (2019) paid special attention to the intangible assets in GVCs. In their opinion, intangible assets protected by intellectual property (IP) rights regulations such as copyright on artistic and scientific works, industrial property and patents on new inventions are increasingly being monopolized with the expansion of GVCs in the last few decades. Consequently, firms in developed countries are enjoying the benefits of rising IP income as well as controlling higher-value economic activities and the creation of competition in lower-value activities in the smile curve. Similarly, Rikap (2021) asserts that intangible assets including patents are characterized by an increasing concentration. The Top 100 innovators are dominated by a small circle of multinationals whose patent portfolios are becoming increasingly determinant compared to other market players. This trend is further advanced by the evolution of the digital economy where success is based on the monetization of knowledge and data, creating an asymmetric market. An increasing number of industries, such as the information and communications technology sector and the health or automotive industries, have experienced an increase in the concentration of intangible assets within the past two decades.

Some studies have further investigated intangible capital and economic upgrading. For instance, Jona-Lasinio et al. (2016) claimed that participation in GVCs in the case of advanced European countries is positively related to intangible capital and R&D (especially in manufacturing), which also brings higher value-added activities. In Hungary, Éltető et al. (2015) found a strong correlation between firm size and intangible investments, indicating that large multinational subsidiaries are more likely to make investments than smaller local suppliers. According to Alsawami et al. (2020), intangible assets may help in the understanding of productivity growth and productivity gaps between frontier firms and laggards because of the different pace at which intangible assets are accumulated. Similarly, Kergroach (2019) noted that the emergence of GVCs presented an opportunity for many emerging economies to join international production networks, facilitating structural transformations and innovation activities. However, middle-income countries seem to have been struggling with improvements in such economic performance in recent years. In Kergroach's opinion, this might be because of the power relations and asymmetry in those GVCs. Among the V4 countries, there is no doubt that the massive inflow of FDI and the emergence of production networks have contributed to the market transition and economic upgrading occurring in the region since the mid-1990s. However, some studies explored the role of local firms in GVCs and their impact on the economic potential of the V4 countries and indicated mixed results. These studies claimed that local suppliers in the V4 countries might not be as innovative (particularly in terms of product innovations) as local firms in Western Europe (Szalavetz 2017; Cieslik et al. 2021). Lee and Gereffi (2021) explained that innovation and upgrading are not merely a result of learning and knowledge transfer with a vertical chain of actors but also due to a broader base of capabilities and newer ways of combining various elements of innovation. In short, countries and companies with better capabilities and more resources are in a better position to benefit from knowledge transfer than emerging economies or newcomer firms.

3. CONCEPTUAL FRAMEWORK: KNOWLEDGE SPILLOVER AND KNOWLEDGE PRODUCTION FUNCTION

Knowledge spillover is considered one of the key factors in innovation. For instance, endogenous growth theories view knowledge spillover as an essential mechanism for sustained technological change and economic growth (Romer 1990; Grossman – Helpman 1991; Eaton – Kortum 1999). Knowledge spillover is defined as the external effect of an existing pile of knowledge; knowledge created in the past can be utilized for future research or research in other sectors/countries. Thus, the stock of knowledge can be considered an input for innovations.

The role of knowledge spillover in innovation can be illustrated in a *knowledge production function*. The concept of knowledge production function was elaborated by Griliches (1979, 1990a, 1990b) and adopted in endogenous growth models (Romer 1990, see Appendix 1). This function is analogous to the innovation and R&D functions and shows that innovation is a function of resources devoted to R&D and the stocks of cumulative knowledge created in the past. A simple knowledge production function is written as:

$$\dot{A} = \vartheta R \mathrm{A} \quad (1)$$

where R is the resources devoted to R&D (e.g. research expenditure and researchers), $\dot{A}$ is the flow of research output (innovations and new knowledge embodied in innovations), and A is the stock of cumulative knowledge created through past R&D. The impact of the stock of knowledge (A) on the current innovation ($\dot{A}$) represents the knowledge spillover. Jones (1995) modified the knowledge production function into a non-linear function. By removing the assumption of linearity, he described the knowledge production function as:

$$\dot{A} = \vartheta R^{\beta} A^{\gamma} \tag{2}$$

where β and γ are the elasticities of research inputs (R and A) to innovation, and the elasticity of the stock of knowledge (γ) represents the magnitude of knowledge spillover. Given the theoretical framework, several empirical studies have investigated knowledge spillover. Coe and Helpman (1995) is one of the pioneering studies, and they investigated international knowledge spillover. By including domestic and foreign stock of knowledge, Coe and Helpman (1995) estimated the elasticity of foreign knowledge on domestic innovations.

Griliches (1990b) argued that a fraction of research output can be patented. In his opinion, the number of patents can be a proxy measure of research output (innovations). By replacing $\dot{A}$ and A with the number of patents (PT) and stock of patents (PTS), Griliches rewrote the knowledge production function as:

$$PT = \vartheta R^{\beta} (PTS)^{\gamma} \tag{3}$$

Empirical studies are increasingly employing patent statistics as a measure of research output. Since the late 1990s, an increasing number of studies have utilized patent statistics as the indicator of knowledge input/output. Verspagen's study was one of the early ones to employ patent statistics by estimating the impact of patents (as the proxy of knowledge) on total factor productivity (Verspagen 1997). Similarly, Branstetter and Sakaibara (1998) used patents to measure the stock of knowledge. Moreover, many recent studies have also utilized patent statistics (Benz et al. 2015; Isaksson et al. 2016; Piermartini – Rubínová 2014; Tajoli – Felice 2018).

3.1. GVCs as a spillover channel

Many empirical studies have examined international knowledge spillover by including domestic and foreign knowledge stocks. International trade and FDI were considered channels of knowledge spillover in many of these studies (Keller 1998; Sakurai et al. 1997; Verspagen 1997; Branstetter 2006). By introducing a spillover channel, the production function can be shown as:

$$PT = \vartheta R^{\beta} (\mathrm{PTS})^{\gamma 1} \left(\mathrm{S} * \mathrm{PTS}_{f}\right)^{\gamma 2} \tag{4}$$

Similar to that of Coe and Helpman (1995), this production function has two knowledge stock variables: domestic and foreign. PTS and PTS_f are the domestic and foreign knowledge stocks, respectively, and the spillover channel, S, is weighted on foreign knowledge stock.

Regarding the knowledge transfer channel, it is important to note that GVCs play an important role in facilitating technology transfer through interactions between buyers and suppliers. Recent studies (Tajoli – Felice 2018; Isaksson et al. 2016) have started paying attention to GVCs as a potential knowledge spillover channel, in addition to already recognized channels such as international trade and investment.

The mechanism through which GVCs facilitate knowledge spillover is yet to be examined. However, some studies have emphasized two main factors: i) the transfer of tacit knowledge through personal interaction; and ii) mutual dependence to encourage the sharing of know-how. For example, Piermartini and Rubiınova (2021: 893) point out that "face-to-face communication with key foreign personnel facilitates the transfer of non-codified knowledge and increases domestic innovative capacity" and "foreign outsourcing firms are more willing to transfer the know-how and technology required for an efficient production of the outsourced input because they will eventually be the consumer of that input." Therefore, the hypothesis to be tested in this study is whether GVCs are also a knowledge spillover channel.

In recent years, various international organizations have been developing quantitative measurements of GVC participation. These measurements include the World Input-Output Database (WIOD), the UNCTAD-Eora GVC database, the OECD TiVA database, and the Asian Multi-Region Input-Output Database developed by the Asian Development Bank (Casella et al. 2019). These databases calculate the GVC indicators from inter-country input-output (I-O) tables and attempt to measure GVCs by looking at the value-added embodied in international trade. For example, the UNCTAD-Eora GVC database includes foreign value-added (foreign value embedded in a country's exports), domestic value-added embedded in a country's exports and domestic value-added embedded in other countries' exports.

Studies on GVC knowledge spillover utilize the I-O based GVC indicators (which are similar to the databases mentioned above) as the weight on knowledge variables. Tajoli and Felice (2018) used the value of all intermediate goods imported by all intermediate goods-producing sectors. Similarly, Piermartini and Rubínová (2014) calculated GVC weights by imported intermediates. These studies took a similar approach to that of Coe and Helpman (1995), weighting foreign knowledge (either cumulative R&D expenditure or patents) by the GVC participation indicator. Most of the studies found that GVCs have a positive impact on knowledge spillover. However, these studies also point out that the impact of knowledge spillover depends on some conditions. For instance, Tajoli and Felice (2018) found that GVCs facilitate knowledge spillover if firms in developing countries have partners in developed economies. Isaksson et al. (2016) stated that the duration of the buyer-supplier relationship influences the knowledge spillover, and Benz et al. (2015) found that GVCs can enhance inter-industry knowledge spillover rather than intra-industry spillover.

4. THE ECONOMETRIC MODEL

This study aimed to examine knowledge spillover by estimating the knowledge production function, which is similar to those in the previous studies discussed above. The knowledge production function with the spillover channel is:

$$PT = \vartheta R^{\beta}(\mathrm{PTS})^{\gamma 1}\left(\mathrm{S} * \mathrm{PTS}_f\right)^{\gamma 2} \quad (5)$$

We considered the aggregate number of granted patents in the V4 as a whole. The model included three foreign knowledge stock variables (i.e. PTS_f): knowledge stock created in the EU (PTSE), North America (*PTSNA*) and Asia (*PTSAS*). The econometric analysis was conducted using a panel data based on eight technological fields between 2006 and 2017. The econometric specification of the knowledge production function is as follows:

$$PT_{it} = \alpha_i + \beta_1 R_{it} + \gamma_1 PTS_{it} + \gamma_2 S{*}PTSE_{it} + \gamma_3 S * PTSNA_{it} + \gamma_4 S{*}PTSAS_{it} + \varepsilon_{it} \quad (6)$$

All variables are in their natural logarithm form. Therefore, the estimated coefficients represent the elasticity of each variable. *PT* is the number of patents granted each year in technology field i and year t. R is the expenditure on R&D as the proxy for the resources devoted to knowledge production. PTS is the cumulative stock of patents invented by the V4 countries. As described above, *PTSE*, *PTSNA* and *PTSAS* are the stocks of patents invented by the EU countries, North America and Asia, respectively. The error term is ε_{it}. Assuming that $\vartheta = e^{\alpha}$, α is the intercept of the estimated equation. As already mentioned, the panel data is sectoral-based; thus, the estimated production function is for sector or industry in the V4 as a whole.

As mentioned above, recent studies have incorporated the impact of GVCs by weighing knowledge stocks. Similar to studies such as that by Tajoli and Felice (2018), this study also weighed knowledge stock by GVC contribution. By including the GVC contribution indicator, our estimating model can be presented as:

$$PT_{it} = \alpha_i + \beta_1 R_{it} + \gamma_1 PTS_{it} + \beta\gamma_2 GVCE_{it} * PTSE_{it} + \gamma_3 GVCNA_{it} * PTSNA_{it} + \gamma_4 GVCAS_{it} * PTSAS_{it} + \varepsilon_{it} \quad (7)$$

where *GVCE*, *GVCNA* and *GVCAS* are the indicators of GVC contribution by the EU, North America and Asia, respectively. Regional GVC contributions are based on exporting countries in the UNCTAD-Eora database. GVC contribution is calculated as described by Cassela et al. (2019). Using the dataset containing the sectoral value-added contribution, the domestic value added embodied in exports (DVX) and foreign value added (FVA) were obtained. As Cassela et al. (2019) described, the DVX is the indicator of forward GVC contribution, while the FVA is the indicator of backward GVC contribution (see Appendix 6). The sum of the DVX and FVA is considered an indicator of general GVC contribution; the weight of the GVC contribution on the patent stock is calculated as the percentage of total foreign and domestic value added (DVA).

The model above was estimated using a random-effects model (cross-section effect).[2] We also estimated our model using FMOLS. FMOLS is advantageous as it addresses serial correlation and endogeneity in regressors. Since the knowledge production function may have potential endogeneity, FMOLS was a more appropriate estimator.

5. DATA

The patent data used in this study were obtained from the EPO. The data included those obtained between 2006 and 2017. This study utilized the number of patents granted in eight technological fields: communication, computer, optics, measurements, food chemistry, chemical, machinery and transport. The dependent variable (*PT*) is the number of patents granted in each technological field each year, while the stock variables (*PTSV4, PTSE, PTSNA and PTSAS*) were calculated by adding the number of patents each year, assuming that stock depreciation occurred at a constant rate.[3] To account for the time lag in knowledge spillover, a 2-year lag in stock variables was included in this study. R&D expenditures were obtained from the OECD Science and Technology Database. Business Enterprise R&D Expenditure (BERD) at 3 digit

[2]The Hausman test failed to reject the null hypothesis that the random effect is preferred.

[3]The depreciation rate was assumed to be 5% per annum. The stock level in the initial year was calculated following Coe and Helpman (1995), which is shown in Appendix 2.

(ISIC) industry level is classified into the eight technological fields mentioned above.[4] As mentioned earlier, the GVC contribution indicator was obtained from the UNCTAD-Eora GVC database.

Unit root tests and cointegration tests of the variables are presented in Appendices 4 and 5. Unit root tests on the variables above were non-stationary at the level; however, they became stationary when the first difference was taken. Confirming that the series were I(1), Kao and Pedroni cointegration tests were conducted. The cointegration tests rejected the null hypothesis of no cointegration, suggesting that there is a long-run cointegrating relationship among the variables.

6. ESTIMATION RESULTS AND DISCUSSIONS

Table 1 shows the estimation results. OLS estimation indicated that the knowledge stock within the V4 countries has a positive impact (0.431) and is significant. By contrast, for foreign knowledge stocks, coefficients were negative or insignificant. FOMLS estimation also showed a consistent result: the V4 knowledge stock had a clear positive impact, with a coefficient of 0.504. The coefficient for PTSE was insignificant, with a negative sign. PTSNA had a negative and insignificant coefficient, and only the PTAS had a positive coefficient (only weakly significant in FMOLS). These estimations do not provide strong evidence of international knowledge spillover.

Table 1. Results of OLS and FMOLS estimations

Dependent variable: Log (PTV4)						
	OLS (Random effect)			FMOLS		
	Coefficient	*t*-stats	*P*-value	Coefficient	*t*-stats	*P*-value
Constant	−1.729	−1.559	0.123			
R	0.278	2.583	0.012	0.279	3.273	0.002
PTS	0.431	3.559	0.001	0.504	4.281	0.000
GVCE*PTSE	−0.080	−0.295	0.769	−0.142	−0.817	0.417
GVCNA*PTSNA	−0.089	−0.192	0.848	−0.267	−1.084	0.282
GVCAS*PTSAS	0.381	1.545	0.126	0.263	1.825	0.072
Adj. R-squared	0.518			0.742		
F-statistics	20.159					
n	90			90		

Source: authors.

[4]The concordance between ISIC and EPO technology fields is presented in Appendix 3.

Our estimation results indicate that innovation in the V4 countries mostly depends on their own knowledge. It seems that international knowledge spillover does not have a positive impact on V4 innovations. The findings are consistent with those of some existing studies on the V4. Stejskal and Hajek (2015) revealed that knowledge spillover is negative for some firms in Czechia due to low absorptive capacity. Prokop et al. (2021) also explained that firms in Central and Eastern European (CEE) countries rely on internal R&D but not on external resources.

Our estimation result seems to support the sceptic view on GVCs' impact. As discussed above, GVCs do not guarantee technology transfer due to the asymmetric power relationship between a GVC and monopolization of IP by the leading firms. Therefore, we can summarize the possible explanations for our econometric findings as follows. First, many MNCs utilize the V4 countries as a low-cost production base, which enables them to specialize in high-value upstream (R&D) and downstream (marketing) activities in the GVCs (see Grodzicki – Geodecki 2016; Natsuda et al. 2020). Consequently, R&D functions in the V4 countries are limited in comparison with their GVC countries. This proposition is consistent with the literature on GVCs (Bair – Gereffi 2001; Pavlínek – Ženka 2011; Rugraff 2010). That is, only low-value activities are transferred to the V4 countries, while high-value activities remain with the MNCs. The results seem to agree with the characterization of the integrated periphery as having a strong dependence on foreign investment, low R&D spending, low capabilities and very few significant domestic suppliers (Mordue – Sweeney 2020).

Second, firms in the V4 countries focus more on supporting (process, production or non-core product-related) R&D, and they do not innovate patentable technology. Instead, patentable research is likely to be conducted elsewhere (typically in a country where a company's head-quarters or regional headquarters are located). Therefore, participation in GVCs does not facilitate knowledge spillover that contributes to patentable innovations. As Tajoli and Felice (2018) pointed out, participation in GVCs may actually exert a negative impact on innovation because it results in the reallocation of R&D activities. Two features should be stressed in the V4 countries. First, local firms may have eroded their innovative capacity as R&D has shifted away from core technology. The Czech automotive industry, which was self-sufficient during the state of socialism, is a typical example. After Skoda Auto was taken over by Volkswagen in the 1990s, the core technology of Skoda became dependent on Volkswagen. Consequently, Czechia has lost access to core technology. Although R&D has been growing in the Czech automotive industry in recent years, the development of advanced technology is limited to non-core technologies such as electronic systems and sensors. Indeed, core technologies such as engines or gearboxes are being developed outside the country (Natsuda et al. 2022b). In short, the Czech automotive industry conducts R&D on peripheral (non-core) technology. In addition, a dichotomy between MNCs and local firms can also be identified in the share of R&D. R&D activities in the Czech automotive industry have been dominated by foreign firms, with 87% of R&D workers employed by foreign MNCs (Pavlinek 2012). Many local firms are more engaged in doing-using-interacting (DUI) innovation with the new technologies rather than in formal R&D-based innovation. Consequently, international competitiveness and export opportunities are very limited for local firms. Second, MNCs only typically conduct process and production-related R&D operations in the V4 countries. Sass and Szalavetz (2014) revealed that R&D in many firms in Hungary tends to focus on local production-related technologies with low complexity. Similarly, Pavlinek (2012) claimed that R&D activities in the V4 do not relate to core technology and that most R&D activities are based on production support.

Third, there is little technology spillover to local firms because technology transfer is confined to MNCs within GVCs. Some studies claim that firms in the V4 countries do not receive sufficient knowledge from MNCs due to their strict knowledge control (Konings 2003; Djankov – Majcen 2000). Once again, our estimation result supports the sceptic view of the studies discussed in the previous section. As Durant and Milberg (2019) and Rikap (2021) asserted, intangible assets are highly concentrated and monopolized by large MNCs, and as a result, core technological knowledge is also confined to MNCs. In this context, many studies on GVCs in the literature assert that knowledge-intensive activities are not transferable and rather remain in MNCs.

7. HUNGARY AS A CASE STUDY

7.1. Hungarian research and innovation performance

According to the European Innovation Scoreboard (2022), among the V4 countries, Czechia ranked 17th out of 27 EU member states (moderate innovator), followed by Hungary (22nd), Slovakia (23rd) and Poland (24th) – emerging innovators. Although Hungary invested 1.6% of its GDP in R&D in 2020, it lags behind in terms of the number of innovative businesses. In terms of patent applications, Hungary is around the middle of the ranking of EU member states (16th of 27 in PCT patent applications), but in other categories of intangible assets (e.g. trademarks and designs), the country is far behind advanced EU economies; other V4 countries are performing better in these fields.

Patenting activities show a two-faced situation in the V4 countries. Judging only by the number of patent owners, all V4 countries' performance lags behind that of many advanced European countries (such as Germany and Switzerland) or older EU member states such as Portugal and Greece. However, if we study the patent inventor information closely, we would find that the number of patent inventors (from the V4 countries) is much larger than that of patent owners. This implies that multinational subsidiaries in the V4 countries tend to patent their internal and external R&D results in their home countries (headquarters) rather than within the V4 countries, and V4 countries' stakeholders are still showing weak intellectual capabilities (Inzelt 2014). This is especially true in the fields of digital communications (from Swisscom through Siemens to Ericsson or Nokia) and pharmaceuticals (Sanofi, Novartis or the Hungarian-owned Richter) where it is quite common to find patents co-invented in Hungary but patented elsewhere (e.g. in the headquarter of a multinational firm). German and other Western European firms are the typical owners of these patents, but many US (e.g. GE and Visteon) and Japanese firms (e.g. Ibiden and NTT) are patent owners, too (EPO 2022). In such circumstances, the V4 countries generally play a supportive role in the R&D activities of MNCs. Moreover, these multinational subsidiaries in the CEE countries only provide the knowledge and information necessary for their suppliers to secure their procurement. Under such a buyer-supplier relationship, many local suppliers are not involved in formal R&D or patenting activities. In a nutshell, local firms in CEE merely rely on the DUI type of innovation activities or on process innovations that may not bring patentable results.[5]

[5]For a discussion on STI and DUI innovation modes, see Parilli et al. (2016).

Hungary steadily increased its R&D expenditures during the 2010s and reached 1.6% of GDP in 2020. Half of this expenditure comes from the business sector, but the share of direct and indirect government support for business R&D is among the highest among EU member states.[6] In contrast, public R&D expenditures are stagnating and lagging behind the expenditures of other EU or even V4 countries. In 2020, around one-third of all R&D expenditures were financed by the government, of which more than 37% was provided by businesses, 34% by higher education, and 27% by public research organizations (Hungarian Central Statistical Office 2022; EIS 2022). It is noteworthy that approximately 60% of R&D expenditures in the business sector come from foreign-owned companies (multinational subsidiaries) which are engaged in export activities in Hungary. Meanwhile, the innovativeness of SMEs is lagging behind that of the EU as well as the V4 averages (Hungarian Central Statistical Office 2022, Eurostat 2022). Moreover, although human resources in science and technology show moderate improvement during the past decade (especially in the business sector), the proportion of people with tertiary education in Hungary remains low compared with other V4 countries (Hungarian Central Statistical Office 2022).

The incremental improvements in the Hungarian innovation system were not insufficient to significantly improve the country's innovation performance. According to the EIS database, Hungary is not meeting up to the EU average and is even moving down in the country rankings. Among the different dimensions of the innovation indicator, Hungary shows a relatively good position in the sales impacts of innovation category, which might be the result of MNCs' high level of high-tech and medium-high-tech export productions. Hungary has also progressed in the fields of digitalization, innovation linkages and substantial public support for business R&D, while a gap between the EU average and Hungary is highest in the number of innovators and the field of human resources.

7.2. The automotive industry in Hungary

To better understand our quantitative GVC model, we used the Hungarian automotive industry as a case study; this industry has been built on the automotive GVCs over the past three decades. Hungary has made immense efforts to attract FDI/MNCs into the country since its transition. Nonetheless, the results of this policy remain odd, because the settled multinational subsidiaries modernized only some parts of the economy, and rather created a dual economic structure (see Boda 2017; Lengyel – Leydesdorff 2015). In 2018, the automotive industry accounted for 27.9% of manufacturing output and 4.9% of GDP in Hungary; it also employed 172,500 workers (3.8% of the total employment). In addition, over 90% of the industry's output was exported (HIPA 2019). In 2023, four multinational assemblers—Suzuki, Stellantis (former Opel), Audi and Mercedes—are engaged in car or engine production in the country. In addition, BMW announced their intention to establish a factory in Debrecen in the coming years. One of the most important aspects of multinational assemblers' relocation is the induction of their supplier's FDI into the host country because multinational Tier-1 suppliers (typically mega suppliers) follow their assemblers to supply their products (Natsuda – Thoburn 2021: Chapter 2). Indeed, over 40 out of the top 100 global automotive parts suppliers operate in Hungary. In addition, there are approximately 700 automotive parts suppliers (HIPA 2019).

[6]According to the EIS database, Hungary ranks 3rd among the EU member states in the indicator of direct and indirect government support for business R&D, just behind France and Austria. Czechia ranked 10th, Poland 12th and Slovakia 20th in this ranking in 2021.

Two types of automotive firms can be identified in Hungary: i) multinational subsidiaries and a few large local capital firms and ii) small local capital firms. The former is typically engaged in export and higher value-added economic activities (including limited R&D activities, too) and also acts as a buyer to procure parts from local as well as foreign suppliers. It is important to note that the local content in these automotive GVCs is rather limited. Gáspár et al. (2020) revealed that backward linkages in the local industry are limited in the Hungarian automotive industry. The main reasons for low local content can be explained by the low technical and human resource capabilities of local suppliers to meet the requirements of MNCs and international competition.

The second type of automotive firm is typically smaller firms with limited human resources (with engineers but no researchers) that cannot afford to conduct their own R&D activities or engage in R&D collaborations with other firms or research institutions. Local firms receive detailed instructions on the production of the parts from buyers and merely produce the products (parts) accordingly. In many cases, they can constantly improve their production system due to an expectation (or pressure) from MNCs' supply chain networks. Local firms regularly renew their technology, for which they command the basic absorptive capacity and employ engineers who are capable of accomplishing such tasks. Apart from a few exceptions, local firms typically do not have a high level of capability and only rely on their existing capabilities (without external knowledge).[7] It is obvious that local firms that employ researchers and conduct R&D activities become more competitive. Nonetheless, it might be difficult for them to achieve this because it is uncertain that such industrial upgrading always leads to economic upgrading. In fact, even downgrading can be a favourable strategy for local suppliers to secure their profit (Blažek 2016). During our interview with a local capital automotive-related firm, we found that although original designed parts provide a higher profit margin per product, such high-value products are relatively limited in terms of total production because volume orders with lower margins secure more profit in the total business operation. Consequently, this firm does not tend to pursue industrial upgrading energetically but rather enjoys economic upgrading.[8] In this context, local firms (particularly SMEs) in Hungary seem to face difficulty in conducting innovative activities.

Regarding innovative activities in the sector, four features should be stressed. First, many MNCs view Hungary as a low-cost production base and thus do not conduct R&D operations in Hungary. For instance, one of the Japanese automotive-related firms operating in Hungary conducts its R&D in Japan, Asia, USA and Germany. In Europe, product and design development is conducted at the head office in Germany. The Hungarian subsidiary merely plays the role of a mass production base.[9]

Second, many multinational subsidiaries conduct R&D in Hungary, but they only target production- and process-oriented R&D (see Natsuda et al. 2022a). In short, MNCs are mainly involved in supporting R&D activities in Hungary. Magyar Suzuki and Audi Hungaria fall into

[7]In such a circumstance, researchers can help local firms to further develop the product (product innovations).

[8]Interview with a director at a local capital automotive-related firm (with 2000 employees) in Hungary on 19 December 2019.

[9]Interview with a senior manager at a Japanese capital automotive-related firm (with 1,590 employees) in Hungary on 17 January 2020.

this category. These R&D activities represent applied tasks strongly related to the production activities of the subsidiaries, and they are far from being strategically important for the MNC's global operations. Indeed, such R&D activities are established, in many cases, due to some available government support. Consequently, their main target is either some improvements in the production technologies or cost reductions, but they rarely result in patentable inventions. It is also important to note that Continental and Bosch – global Tier-1 suppliers – conduct more significant R&D activities in Hungary.

Third, local SMEs can access a certain technology through production networks, which enable them to conduct process and product development. However, key technologies tend to be owned by lead firms. During an interview, we found that one of the local capital automotive component suppliers conducts product development of mould products.[10] When this firm develops products, these products are assessed and approved by the customer (assembler) who then pays the die arrangement and ownership fees to the local firm. In short, dies in this firm are owned by the assembler. In this way, technology transfer is confined within the assembler's production network.

Fourth, patenting activities in local firms that develop new products and designs rely on individual business decisions because the firm's size and their ability to enforce their interest (and influence) on the market are extremely limited, specifically against MNCs. In many cases, these firms prefer to rely on trade secrets or try to embed their specific knowledge in their product. In this way, they can ensure that their knowledge is not stolen by their competitors. As a result, despite their R&D efforts, much fewer patents are applied by these companies. In short, innovative patentable technology is not developed in such firms. In our interviews, a local capital automotive firm with an R&D division[11] and a small R&D-intensive specialized SME[12] fell into this category.

8. CONCLUSIONS

This paper has empirically examined knowledge spillover in the V4 countries, focusing on the role of GVCs. Our estimation results indicate that international knowledge spillover contributes very little to the innovation of the local economy in the V4 countries. Contrary to the conventional expectation, GVCs do not significantly facilitate knowledge spillover. This finding may be attributed to three factors: i) MNCs' strategy to locate a low-cost production base, ii) MNCs' strategy to locate supporting (process, production or non-core product related) R&D activities, and iii) limited technology spillover from MNCs to local firms in the V4 countries. The case study of the Hungarian automotive industry portrays these issues, too. First, automotive MNCs view Hungary as a low-cost production base; hence, many firms do not conduct R&D in the country. Second, even though R&D is conducted by MNCs, it is typically directed toward supporting R&D. Third, MNCs tend to keep their knowledge strictly within their production networks. Thus, knowledge does not effectively diffuse into the local firms. Indeed, many local

[10]Interview with the managing director of a local capital automotive-related firm (with 140 employees) in Hungary on 29 January 2020.

[11]Interview with a director at a local capital automotive-related firm (with 2000 employees) in Hungary on 19 December 2019.

[12]Interview with the CEO of a local capital R&D firm (with 17 employees) in Hungary on 17 January 2019.

SMEs cannot conduct R&D due to insufficient technological and human resource capabilities. For these reasons, Hungary (as well as the other V4 countries) falls into a typical integrated peripheral state. Overall, local firms in the V4 countries have not been encouraged to conduct R&D on core technologies, and they have become dependent on peripheral products and technologies provided by MNCs. As a result, local R&D activities in the V4 countries have been diverted from patentable innovation.

ACKNOWLEDGEMENTS

We would like to thank the Japan Society for the Promotion of Science (KAKENHI Grant No. 17KK0059, No. 21K01475) for research financing and the Centre of Excellence for Future Value Chains at Budapest Business School.

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APPENDIX

Appendix 1. Knowledge production function in the endogenous growth model

The endogenous growth theory by Romer (1990) is a two-sector growth model consisting of output production (goods and services) and knowledge production (R&D and innovation).

$$\mathrm{Y} = K^{\theta} L^{1-\theta} A^{1-\theta}$$

$$\dot{A} = \vartheta R\mathrm{A}$$

The model illustrates that R&D enters into output production as an improved production technology. Firms in the economy conduct R&D to create new products or improve existing ones. The knowledge created in the R&D sector piles up and is fed back into R&D activities in other firms or into future R&D.

Appendix 2. Patent stock in the initial year

According to Coe and Helpman (1995), the stock value in the initial year is calculated using the following formula:

$$PS_0 = \frac{P_0}{0.05 + \varnothing}$$

where P_0 is the number of patents (flow) in the initial year 0. The depreciation rate of the stock variable is assumed to be 5%. Ø is the average growth rate of the number of patents. The values of initial patent stocks in each technological field are presented in Table A1.

Table A1. The value of the initial patent stock

	Czechia	Hungary	Poland	Slovakia	Total V4
Communication	1.931	0.000	8.116	0.000	10.047
Computer	0.000	0.000	0.000	0.000	0.000
Optics	3.333	3.032	0.000	0.000	6.366
Measurements	1.475	8.750	0.000	0.000	10.225
Pharmaceutical	3.023	27.770	0.000	13.548	44.341
Food Chemistry	9.130	0.000	4.693	0.000	13.823
Chemical	4.317	2.947	3.978	0.000	11.242
Machinery	25.652	16.051	2.444	3.962	48.110
Transport	11.018	0.000	4.478	0.000	15.496

Appendix 3. Concordance of EPO and ISIC

Table A2. EPO classifications and ISIC Rev.4

Category	EPO	ISIC Rev 4
Communication	Digital communication + Basic communication + Telecommunication	263
Computer	Computer	262
Optics	Optics	267, 268
Measurements	Measurements	265
Pharmaceutical	Pharmaceutical	21
Food Chemistry	Food Chemistry	10T11, 10T12
Chemical	Basic materials chemistry + Chemical engineering	20
Machinery	Machine tools + Textile and paper machines + Other special machines	2B
Transport	Transport	29

Appendix 4. Unit root test results (statistics from Levin-Lin and ADF tests)

Level						
	PT	**R**	**PTS**	**GVCE*PTSE**	**GVCNA*PTSNA**	**GVCAS*PTSAS**
Levin-Lin & Chou	−1.93**	−1.28	−1.52*	0.46	0.84	1.63
IPS	−0.15	0.70	2.08	1.54	2.14	3.53
ADF	21.00	12.88	12.41	6.93	5.49	2.66
1st difference						
	PTV4	RDV4	PTSV4	GVCE*PTSE	GVCNA*PTSNA	GVCAS*PTSAS
Levin-Lin & Chou	−12.34***	−13.3***	−6.81***	−3.54***	−3.90***	−3.71***
IPS	−8.77***	−8.9***	−4.62***	−5.07***	−4.93***	−4.57***
ADF	93.78***	91.1***	55.35***	54.94***	53.71***	50.31***

Note: ***, **, and * indicate that the null hypothesis of unit root is rejected at 90%, 95%, and 99% confidence level respectively.

Appendix 5. Panel cointegration test results

Pedroni Residual Cointegration Test		
	Statistic	**Prob.**
Panel PP-Statistic	−4.507	0.000
Panel ADF-Statistic	−3.065	0.001
Kao Residual Cointegration Test		
	t-Statistic	Prob.
ADF	−6.371	0.000

Appendix 6. GVC contribution

As described by Casella et al. (2019), GVC contribution is calculated using the data on value added trade. The matrix shows the value added contained in the exports of each country. F11 is the domestic value added of the exports of Country 1. F21 is the value added by Country 2 contained in the exports of Country 1 as well as the value added by Country 1 in the exports of Country 2. In the matrix below, the columns show the sum of domestic value added and foreign value added (FVA) in Country 1. Similarly, the rows show how much of each country's domestic value added is embodied in the exports of other countries (DVX). The GVC contribution is the sum of FVA and DVX.

	Country 1	Country 2	...	Country N	
Country 1	F^{11}	F^{12}	...	F^{1N}	→DVX
Country 2	F^{21}	F^{22}	...	F^{2N}	
...	...	...	...		
Country N	F^{N1}	F^{N2}	...	F^{NN}	
	↑FVA				

Source: Casella et al. (2019).

$$\text{GVC contribution} = \text{FVA} + \text{DVX}$$

$$\text{GVC weight} = \frac{FVA + DVX}{FVA + DVA}$$