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DISSERTATION

Essays on the Impact of Technological Change on Economic Structure

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Declaration of Authorship

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Abstract

JEL Classification	O32, O33, O47, L14, F02, F14
Keywords	research and development, global value chains, technology transfer, foreign direct investment
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Abstrakt

Klasifikace JEL	O32, O33, O47, L14, F02, F14
Klíčová slova	výzkum a vývoj, globální hodnotové řetězce, přímé zahraniční investice, technologická výměna
Název práce	Eseje o vlivu technologické změny na strukturu ekonomiky

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Chapter 1

Introduction

One of the key tasks of economics is to figure out where economic growth comes from and discover tools to stir it in places suffering from economic sluggishness. Increasingly sophisticated exogenous growth models showed that catch-up, per-capita growth can be driven by accumulation of capital. The capital accumulation, however, sooner or later reaches the steady state, and the soaring economy hits the ceiling of its employed technology (Solow 1956). The failure to explain the changes in growth once the optimal capital intensity has been achieved led to the new, endogenous growth models where technological progress is endemic to a long-run economic growth (Romer 1994).

Internalizing technological progress into the models raises the question of what technology is. Empirically, we often label everything we cannot measure in the framework of production function as technology (Van Beveren 2012). Indeed, Abramovitz (1993) coined the total factor productivity (TFP) as "the measure of our ignorance". The first tries to bring more light into the problem diminished the problem, but the residual remained comparatively huge. Brinkman (1995) even scolded some of the endeavors of looking into the black box of TFP with a quip: "...while Scott did indeed look into the black box, he forgot to bring a flashlight". Reflecting the progress of last decades, such assessment seems a bit too harsh. Since the inception the TFP concept, successful attempts have been made which show how changes in TFP can be explained by various factors – among others human capital (Benhabib & Spiegel 2005; 1994; Vandenbussche *et al.* 2006), openness to trade (Danquah *et al.* 2014) or entrepreneurship (Aparicio *et al.* 2016).

Conceptionally, we can distinguish between technology which is the crude technological advancement and social capability which is essential in production but is more elusive and includes institutions, norms and even culture (Abramovitz 1986). We thus have a framework for explaining why certain countries catch up with the technology leader more successfully than others – which we know it is the case (Romer 1990; Grossman & Helpman 1990; Griliches 1998; Keller 2004; Lee & Tan 2006; Hidalgo *et al.* 2010). Moreover, it seems that technological change plays greater role in economic development than capital accumulation (Badunenko *et al.* 2008). But the catch-up process is not just a function of the technology gap, and so it is worthwhile to investigate the sources of the technology transfer and identify the right economic policies which can be used for stirring economic development around the globe.

Because technology is not uniform around the globe, it is natural to assume that one of the important drivers of progress is technology transfer. And since large portion of international contact is facilitated by trade and related investment, it is trade and international investment that are often linked to technology transfer (Castellacci 2011; Danquah *et al.* 2014; Botric *et al.* 2017). However, the trade itself changes. There has been only a vague notion of how a more recent transformation of international trade cooperation, global value chains (GVCs), contributes to the dissemination of technology and thus to economic catching-up. Rodrik (2018), for instance, suggests that GVC participation and technology does not lift all the boats and the effects are thus heterogenous with a potential of harming the developing economies. This thesis investigates the heterogeneity of these effects further. We complement the literature on trade and its effects on economic development with special focus on heterogeneous effects of GVCs in different countries with distinct economic structure. The thesis is also an addition to studies focused on different channels of technology transfer such as FDI (Braconier *et al.* 2001), academic research (Freitas *et al.* 2013), or local sites developed by multinational corporations (Wang & Zhou 2013).

Inherent technological progress is related to or even derived from research and development (R&D). It is not only the source of the new technology but also a likely catalyst for the technology transfer. Domestic R&D capacities can serve as a prerequisite for adoption of new technology from a technologically more advanced partner. Moreover, data for R&D is widely available and comparable across countries. We thus have estimates of the R&D spending effects on country's productivity (Hall *et al.* 2010), indirect R&D returns (Lucking *et al.* 2018), or even see of how R&D prowess serves as an enabler of technology transfer for the receiving countries (Teixeira & Fortuna 2010). R&D capabilities can partially explain the heterogeneity of countries' development as well as their capacity for adopting the frontier technology of their trading partners.

R&D is likely to influence the technology transfer, but the impacts of GVC participation are defined also by the architecture of the value chain. With strict hierarchy between the GVC agents, even improved R&D capabilities may not help the country to take responsibility for more complex tasks and thus obtain greater value added (Grossman & Rossi-Hansberg 2008; Gereffi *et al.* 2005). Distribution of tasks along the value chain influences for both value-added distribution and technology transfer. Investigating only GVC participation thus pools two effects together: the technological and the hierarchical. Whereas it is hard to imagine that international trade, even in its value chain form, can cause technological drawbacks, it is possible to imagine that hierarchical international trade may be a hindrance in country development. As a supplier, one can become more productive at production of the specific product, but it may be very difficult to move up in the production chain and obtain greater share of the total value added (Humphrey & Schmitz 2002). This may be especially the case for developing countries that are not focused on tasks associated with high valued added (R&D, marketing, headquarter activities) as they lack the multinational corporations which usually sit at the center of the value chain (Gereffi *et al.* 2005).

As industrial policy comes back in vogue, the implications of our findings are increasingly relevant. Ideas such as strategic autonomy may have to be assessed more broadly. As this thesis suggests, the effects of such policies may vary country from country, industry from industry and may depend upon variety of cofounding factors. The same applies to development policies of non-OECD countries. We add to the vast body of literature that provides a comprehensive account of how industrial policy specifically focused on fostering or stifling international cooperation in one way or another makes a huge difference in the respective countries' fortunes (Harrison & Rodríguez-Clare 2010; Stiglitz *et al.* 2013; Warwick 2013; Aghion *et al.* 2015). It should be stressed out, however, that the current knowledge describes technological framework of today. Baldwin *et al.* (2014) foretells the third unbundling (after industrial and ICT revolutions), which may change the rules of the game entirely.

Apart from the risk of not describing the world of tomorrow, our approach has naturally other limitations. The main obstacle lies in the specification which does not allow for causal interpretation. Thus, the results have solely explorative character. This is caused by the current unavailability of more detailed data which would allow for claims of causality. The limitation of the data also restricts the number of concepts it is possible to investigate empirically. As mentioned above, social capability or absorptive capacity are very rich notions which, sadly, have to be only approximated by quantitative measures such R&D capital stock, FDI stock, or functional specialization. The research is thus only hinting on the links between the greater notions, potentially missing the most important interplays which are, due to data unavailability, omitted.

This is something, which can be improved upon greatly. There is increasing amount of data being collected privately, in firms which focus on supply chains, and international trade. Such data can be increasingly used in more elaborate model specification which would get closer to proper causal identification. Similarly, covid pandemic presents itself with myriad of exogenous shocks which can be used in quasi-experimental designs to see, for instance, whether GVC participation really causes economic development or whether it merely accompanies it.

This thesis covers technology transfer in three stages. First, I investigate R&D returns, both their direct and indirect kinds. Second, I inspect GVC participation and its links to sectoral productivity. Lastly, I bridge these two papers with an inquiry into the catalysts of technology transfer, specifically whether the R&D and FDI can stimulate the benefits which GVC participation provides.

Chapter 2 – *Heterogeneity of Returns to Business R&D: What Makes a Difference?* begins the inquiry into technology transfer by estimating R&D returns to in Czechia. Apart from estimating direct R&D returns which surprisingly has not been done for Czechia, spillover effects are also estimated with respect to specific channels. I thus distinguish between spillovers from privately and publicly funded R&D, whether they happen in upstream or downstream directions of the production process. It is important to have such estimates as R&D spending should reflect not only the direct gains of the spender, but also the aggregate social benefits which are impossible for the spender to monetize. Such distinctions are not common in the literature and are especially novel in the Czech context.

To estimate the R&D returns, I follow Hall *et al.* (2010) and construct the R&D stocks from annual R&D spending data. I then use standard Cobb-Douglas production function to get a regression equation yielding the final estimates. Such approach allows for calculating the public and private R&D stock separately. I further use input-output tables to estimate the links between sectors with the assumption that intensive trade links can be used for technology transfer (Eberhardt *et al.* 2013). I calculate shared R&D stock which is R&D stocks of other sectors weighted by the linkages obtained from the input-output data. The structure of the input-output data allows to further distinguish between the forward (downstream) and backward (upstream) links.

I find that privately funded R&D has positive direct effects whereas the publicly funded R&D spending benefits the economy mainly indirectly, via spillovers. However, direct effects of privately funded R&D are also positive and statistically significant. Estimates of the spillovers which happen through forward and backward linkages show that the technology transfer happens in both directions, although the forward link is the more prevalent one. Furthermore, there seems to be a critical mass required, so that the return of privately funded R&D can materialize. This is not the case for publicly funded R&D. The returns to R&D do not stay intact over time. Financial crisis affects the estimates significantly. While the returns to private R&D soared during the crisis (selection bias might be a chief culprit, as those who managed to keep their R&D spending up were likely those, who were less affected by the crises), the returns to publicly funded R&D turned negative â€“ possibly because of R&D support being used as fiscal help for those most severely hit by the crisis.

The results of this chapter shows that the most straightforward proxy for technology, R&D, indeed relates to value added and that such a form of technology dissipates through the economy is hardly trivial. Moreover, the dissipation can be strongly influenced by policy – by public spending but also through creating environment where tacit knowledge spreads faster and more efficiently. The policies should be also weighted against each other as R&D subsidies for firms, tax credit related to R&D or direct public R&D spending are likely to yield different results. Public R&D expenditures taken as an aggregate variable thus may not provide sufficient detail.

Chapter 3 – *Who Benefits from Global Value Chain Participation? Does Functional Specialization Matter?* focuses rather on international technology transfer, specifically, on the effects of GVC participation. There is ample evidence that international contact can be good for technology diffusion (Schneider 2005) but the novel organization of trade, namely GVCs, poses a new question of whether the technology diffusion happens across the whole chain and whether the improvements in productivity are not offset by the effects of stringent GVC hierarchy which is often embedded in the GVC organization.

That the distribution of value added is not distributed evenly across the production chain and that the distribution has a U-shape has been known for decades (Shih, 1992). But the effects of GVC participation based on the role of that the country, industry or a firm plays and the role its partners in chain has been neglected. Using functional specialization at the industry level, I estimate the relations between value added and a particular kind of GVC participation. I can thus distinguish between GVC participation related to R&D, fabrication, and marketing which, to my knowledge, has not yet been done. The amount of transferable knowledge can vary between the functional specialization as well as it may depend on the functional specialization of the GVC partner. Because of the U-shape of the value-added distribution, I focus mainly on fabrication as those specialized in this business function. Indeed, this is the stage with the least capabilities and prone to absorb the most technology from international contact.

Empirically, foreign value-added share obtained from input-output tables serves as the proxy for GVC participation. The estimation strategy uses the standard Cobb-Douglas production function, similarly to other researchers (Kummritz *et al.* 2017). The benchmark estimates show positive relationship of GVC participation and value added. Not the whole relationship can be attributed to technology transfer. The causality likely works both way and the hierarchical effects of GVC participation surely play a role too. This is confirmed by the crucial finding that GVC participation benefits increase with fabrication specialization. Since fabrication is not associated with dominant role in the GVC hierarchy, it is sound to assume that technology transfer (though not necessarily in the intentional and codified way) is especially present in such a setting.

Focusing on functional specialization of the GVC partner, I have found that GVC partners linked to marketing are the least beneficial. This again confirms the theories of strict GVC hierarchy with central firm controlling the whole value chain, but particularly the sales. Being a mere contractor is thus not as profitable role in a GVC – a finding in line with existing evidence (Stöllinger 2021). From the perspective of fabrication-oriented industries, it is GVC partner focused on R&D that provides additional benefit of GVC participation. The attention to business function overshadows the country dimension of the GVC organization. I hypothesize it, and rightly so – country differences are mainly due to the fact their distinct business focus, not due to some other underlying characteristics. That said, there is still some remaining, and not surprising heterogeneity. Low-developed countries disproportionately gain from contract with R&D focused GVC partners. Contrarily, dealing with fabrication-oriented partners yield small benefits for them than it does to high-developed countries. Because GVCs are often organized within a single industry, I also investigate the benefits intra-industry GVC participation links to value added. Indeed, the benefits of intra-industry GVC participation are significantly greater than those of its inter-industry kind.

I have successfully showed that there is indeed technology transfer happening through GVCs and that the intensity by which it happens is likely heterogenous. The implications for industrial and trade policy of both developed and developing nations are significant. For instance, the realization that GVC participation with R&D focused partners yields benefits to everyone, but especially to fabrication-oriented industries serves as an argument for trade openness of the developing countries. There are, however, more policies which could affect the absorption capacity of a country and thus enhance the technology transfer happening within GVCs.

Chapter 4 – *Heterogeneity of GVC Participation Effects and Its Catalysts* delves more into the drivers of the technology transfer. Bridging the insights from the two previous chapter, I inspect how R&D affects the relationship of GVC participation and value added. R&D stock is a decent measure of technological competencies which define both absorption capacity as well as prerequisites for optimal positioning within GVCs. It has been established in chapter 2 that R&D has both direct and spillover effects. This chapter develops this argument even further by showing that R&D can be a conduit of positive effects of other phenomena, such as GVC participation or FDI. FDI being one of the modes of GVC participation only with tighter links and stricter hierarchy, it is an ideal comparison for the results that the standard proxy of GVC participation, foreign value-added share, yields.

The international trade-R&D-productivity nexus has been investigated (Teixeira & Fortuna 2010; Ali *et al.* 2017). However, GVCs, to my knowledge, enter the picture for the first time in this paper. I build on the previous papers both with respect to data and methods. I restrict the analysis to the Czech data, so the results admittedly have limited external validity. Despite that, the analysis provides interesting results as it shows that R&D stimulates the benefits from GVC participation only with developed countries. The findings are quite intuitive as they suggest that it is mainly the technology transfer which benefits Czech industries through GVC participation with more developed countries.

There is no evidence for capability build-up through R&D spending and subsequent dominance in GVCs containing less developed countries in the Czech context. Interestingly, the empirical analysis also finds that R&D does not stimulate the returns to inward FDI suggesting that stricter hierarchy leaves less space for other conductive factors such as absorptive capacity.

Understanding technology transfer is difficult task. Concepts that we use are constantly in flux. GVCs is the most actual phenomenon, but it is not difficult to imagine a different organization of international trade. Baldwin *et al.* (2014) envisages the possibility of easy quasi-physical personal transportation which can bring about the new unbundling. Yet, even partial understanding of how technology is created, how it affects the economy and how it spread between countries and industries stimulate efficient policies which in turn stimulate economic growth. And economic growth is the tool for solving other pressing economic, social, and environmental issues. I hope my essays contribute in their modest manner to these noble ends.

Chapter 2

Heterogeneity of Returns to Business R&D: What Makes a Difference?

2.1 Introduction

Research and development (R&D) is a driving factor for economic development. Not only do firms increase their own productivity through R&D investment (Hall *et al.* 2013), but R&D spending also affects other firms through spillovers (Chen *et al.* 2013). Because of these spillover effects on other firms, privately funded business R&D tends to be suboptimal from the societal perspective. One of the purposes of public support for business R&D is thus to compensate insufficient private R&D spending (Gil-Moltó *et al.* 2011). For a comprehensive view of business R&D deliverables, it is therefore necessary to consider returns to both private and public R&D as well as direct and spillover effects of R&D (Eberhardt *et al.* 2013).

Direct returns to R&D have been estimated several times since the first landmark study by Griliches (1979). A firm's knowledge stock has repeatedly been shown to be positively associated with its productivity (Ortega-Argilés *et al.* 2010). Realizing that direct R&D returns of this kind might only represent a fraction of the total returns to R&D, however, Bloom *et al.* (2013) demonstrated that technology spillovers are also important. Technology spillovers depend not only on the investor but also on the recipientâ€™s ability to receive the existing knowledge. For instance, R&D spending enhances absorptive capacity, which stimulates catching-up with the technology frontier

(Griffith *et al.* 2004). It is important to keep this in mind when analyzing returns to R&D in less developed economies as the less developed economies often lack the prerequisites for successful technology adoption.

Because private and public funding for business R&D spending are differently motivated, the nature of their effects is also likely to vary. Surprisingly, however, the existing studies have largely focused on either private or public returns to R&D and have only rarely considered both. The main exception is Furman *et al.* (2006), who focus on spillovers and distinguish between public and private R&D effects. Acosta *et al.* (2015) link public R&D support to greater labour productivity but do not compare any equivalent effect from private R&D expenditures. More attention has been devoted to the effects of public R&D support on private R&D spending; most of the studies on this topic have found that public R&D support stimulates private R&D spending rather than crowding it out (Becker 2015).

The difference between private and public funding is, of course, not the only source of heterogeneity in the returns to business R&D; demand-driven and supply-driven spillovers, for example, must also be considered as distinct technology diffusion channels. It is customary to focus only on spillovers in the downstream direction (Cheng & Nault, 2007; Wilson, 2001) or to use proximity measures that fail to distinguish the kind of linkages (Lucking *et al.* 2018). Wolff & Ishaq Nadiri (1993), Forni & Paba (2002) and Plunket (2009) consider both directions separately, but not in the context of public and private R&D. Finally, the effects of R&D investment are likely to be non-linear (de Meyer & Mizushima 1989) and fluctuate along the economic cycle (Hud & Hussinger 2015), yet their fluctuation has hardly investigated in the literature.

Our aim in this study is to address these gaps in an integrated way. For this purpose we carry out an econometric investigation based on panel data from Czechia at the detailed sectoral level for the period 1995-2015. The results indicate that the direct returns to privately funded R&D are positive and statistically significant at conventional levels but the returns to publicly funded R&D are neither positive nor statistically significant. That is not to say that public support for business R&D has no effect, however: both privately and publicly funded R&D investments create positive spillovers. Splitting those R&D spillovers along the upstream/downstream distinction shows that although the downstream course is dominant, some benefits are felt in the upstream direction. The results also suggest that private R&D only offers significant returns after reaching a critical mass, whereas we do not see this non-linearity in the effects of the public component. Finally, the returns to privately funded R&D were considerably larger after the great financial crisis of 2008, while the returns to publicly funded R&D support decreased. Meanwhile, the spillovers from both types of investment remained unaffected by the crisis.

These results are of particular importance for latecomer economies that are rapidly catching up with the technology frontier through business R&D expenditures, and for which evidence of returns to R&D is scant, as the existing literature has predominantly focused on developed countries. The Czech economy provides fertile ground for studying these effects. Czechia increased its business R&D expenditures as a fraction of GDP from 0.62% in 1995 to 1.13% in 2017, ending up on par with the Netherlands and the UK and overtaking Spain, Portugal, and Italy. The Czech government supported business R&D to the fourth largest extent in the EU between 1995 and 2015 (Eurostat 2019). Nevertheless, analysis of this spending has so far been limited to two studies by Klímová *et al.* (2020) and Sidorkin & Srholec (2017), both of which focus on the additionality effects of both public subsidies and private R&D spending.

The rest of this paper is structured in the following way: section 2 introduces the theory, explains the key concepts and reviews papers relevant to this study; section 3 presents the data and methods; section 4 interprets the empirical results and section 5 concludes.

2.2 Theory and Conceptual Framework

Griliches (1979) produced a pioneering analysis of R&D returns using the production function. He introduced R&D capital stock as an additional input in the production function, which made it possible to estimate the effects of R&D on output. This approach has since been used extensively in the literature on this topic.[1] Moreover, it has drawn attention to R&D spending as an engine of economic progress. In an age of decelerating productivity, public support for R&D is a prominent part of discussions about economic policy (European Commission, 2010).

Policymakers are, or should be, interested in the efficiency of public R&D support. In theory, such support is justified: firms invest in R&D with the vision of raising their future profits, but because those profits can be highly

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[1] For a review of the empirical literature, see McMorrow & Röger (2009).

uncertain and the benefits of R&D are often not easy to internalize, private R&D investment could be seen to be suboptimal from the societal perspective. Government R&D subsidies and public research programmes are thus designed to compensate firms for the benefits that their R&D provides to other firms and to facilitate research with high social returns where there is no profitable business model.

In practice, state incentives for R&D either take the form of direct subsidies or involve indirect tax deductions for R&D spending. Whereas tax incentives usually cover all sectors engaging in R&D equally, direct subsidies address specific industries and technologies, so the government can then steer its support to projects with the highest social returns, including spillovers. Whether this is done successfully is a different matter. In his review of R&D and productivity growth, Sveikauskas (2007) concludes that only privately financed R&D offers high returns and that publicly financed R&D yields only indirect effects. Coccia (2010) finds that public R&D spending complements private spending only if the former does not exceed the latter. Public R&D support does not seem to crowd out private investment (Czarnitzki & Lopes-Bento 2013), and there is even some evidence that public R&D support can boost privately funded R&D (Guellec & Van Pottelsberghe De La Potterie 2003). A review of crowding-out and additionality effects is nonetheless inconclusive (Becker 2015; David *et al.* 2000; Zúñiga Vicente *et al.* 2014).

The standard variable used to capture spillovers in the relevant research is the weighted sum of all R&D capital stocks, where the weights reflect the relative proximity between the subjects of interest (Hall *et al.* 2010). One way of estimating the closeness between countries, industries or firms is to follow Jaffe (1986) and calculate an uncentered correlation matrix of R&D stocks (Bloom *et al.* 2013). For the purposes of industry analysis, however, trade-based weights that consider trade as a spillover vehicle are more appropriate. Coe & Helpman (1995) used import shares, assuming that close trade relations lead to technology and knowledge diffusion opportunities. In this study, we follow Meda & Piga (2014) in using an input-output structure to estimate the connectedness of the industries.

Based on the input-output matrix, we can calculate both forward and backward trade linkages. This enables us to distinguish between the directions of the technology spillovers. Wolff & Ishaq Nadiri (1993) consider spillovers in both directions, but they find only the forward direction significant. Forward linkage is usually the only spillover direction considered, since it is assumed that better inputs will increase product quality or process efficiency. Backward spillovers are largely neglected in the literature, with just a few exceptions (Forni & Paba 2002; Plunket 2009). Yet the customer's technological progress may also drive suppliers to innovate, and this is especially likely in tightly knitted value chains where central firms with many sub-suppliers define the production process (Gereffi *et al.* 2005).

Distinguishing between forward and backward spillovers helps us to differentiate between technology and rent spillovers (Mohnen 1997). Rent spillovers affect the suppliers in the industry concerned, and thus spread mainly backward; this makes them likely positively biased in the empirical estimation. Without that bias, backward R&D spillovers may even be negative. Dietzenbacher & Los (2002) state that R&D costs are reflected in output prices, which negatively affects downstream industries. They further show that backward and forward linkages are heterogeneous, which means that using them as weights yields independent measures of shared R&D capital and this dispels fears of collinearity in the estimation.

Forward and backward spillovers may play a special role when it comes to public R&D support. Direct public support is essentially a fiscal stimulus and so, even with no technology gains, it can have a positive effect on the receiving sector. Moreover, such a positive effect should spill upstream to other industries via rent spillovers (Mohnen 1997). Thus, if we measure knowledge spillovers based on the suppliers' shared knowledge pool, this may produce an overestimation. However, there is little reason to assume that the simple fiscal effect trickles down and benefits downstream industries to any large extent, hence the bias in the latter direction should be small.

Estimations of R&D returns for whole economies often allow no space for heterogeneity, although there are some exceptions. Based on the rationale of Cohen & Levinthal (1990), Griffith *et al.* (2004) find that industries with lower R&D intensity profess faster productivity growth than the technology forerunners and that technology transfer can be further induced by the receiver's absorptive capacity. Braconier & Sjöholm (1998) provide a comprehensive study on both inter and intra-industry spillovers, showing that both exist. The heterogeneity of R&D effects could also depend on the level of R&D spending itself. Low levels of R&D investment may only have a minuscule effect and substantial returns might materialize only after a critical mass of R&D capital is achieved (de Meyer & Mizushima 1989).

Another strand of literature has explored the distinction between private and public R&D spending in the estimation of their interplay with productivity. Segerstrom (2000) provides a theoretical framework for the long-term effects of public R&D spending, but with little empirical evidence. Haskel & Wallis (2013) show that public R&D spending (specifically on research councils) spills over to market sector productivity. Other papers have focused rather on direct impacts on firm behaviour (Busom 2000). Firm-level studies are perfectly fit for the matching approach in the analysis (Almus & Czarnitzki 2003), but this technique neglects the magnitude of the public - which is crucial for policy evaluation - as it only uses a binary distinction between treated and not treated.

Microdata are suitable for estimating direct effects from R&D as they provide great detail and statistical power, but they are less fit for evaluating spillovers. Despite the fact that R&D spillovers happen between firms at the micro-level, it is not clear how to assess the degree to which firms interact with one another. Spillovers are thus generally neglected in evaluation studies based on microdata (Baumann & Kritikos 2016). Industry-level data, on the other hand, provide the opportunity to relate one industry to another through input-output tables and, based on this measure, to estimate the indirect spillover effects of R&D spending. The downside of using this approach is that intra-industry spillovers are neglected, but it can still provide some useful insights.

2.3 Data and Model

The Czech Statistical Office (CZSO) conducts an annual survey on R&D, covering all firms that CZSO believes to have R&D activities. The data on R&D spending can be split according to the source of financing - private or public - and the nature of the expenditure - current or investment. The survey's response rate oscillated around 84 percent over the years 1995-2015, which is high in international comparison. Nevertheless, some data was still missing due to non-response.[2]

CZSO provides data on value-added, labor, and capital at the detailed NACE 120 level.[3] The R&D data has been aggregated to match this clas-

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[2] We can never be sure whether a missing observation is a non-response or whether the firm ceased its R&D activity. Extrapolation of the missing data is not feasible, because some firms might have ceased operations during the covered period, but it is possible to interpolate the missing data within a time series, because R&D expenditures do not drop to zero for just a few years, especially in large firms. We thus interpolate data on firms with more the 250 employees if the gap between their observations is no more than three years.

[3] NACE 120 is a combination of NACE two-digit and three-digit numerical distribution (i.e. divisions and groups).

sification. Because many of the NACE 120 industries are barely engaged in R&D, we focus on 61 manufacturing and selected service industries, for which the R&D statistics are reliable.[4] This subset of industries accounts for more than 90 percent of all R&D spending. An overview of the sectors included in the analysis is provided in Appendix A1. Only data from private companies are used in the analysis, so that we analyze only business R&D returns and spillovers; we do not mix research at public universities and public research institutions into our analysis. All the monetary variables are transformed into 2010 prices in CZK using sector-specific deflators.

The timing of R&D effects is difficult to pin down (Hall *et al.* 2010). To deal with this problem, we construct a measure of R&D capital stock for each sector. Using stock instead of flow variables enables us to relate past R&D expenditures to current productivity. Hence:

$$R_t = (1-\delta)R_{t-1} + r_t \tag{2.1}$$

where R_t is the R&D capital stock at time t, r_t is the R&D expenditure at time t, and δ is the depreciation rate. The depreciation rate is a parameter set to 15%, which is standard in this literature (Hall *et al.* 2010) but note that its value does not affect the estimates in any significant way. After logarithmic transformation, the rate becomes a constant that only affects the fixed effects estimation to a limited extent.

For our iterative approach we need to determine the level of R&D capital at time 1. Following Hall *et al.* (2010), we assume that R&D expenditures have a constant growth rate (which is supported by the empirics) and constant depreciation rate:

$$R_2 = \frac{r_1}{g+\delta} \tag{2.2}$$

The estimation dataset covers the years 1996-2015. The flexibility of the R&D capital stock model, however, enables us to differentiate between publicly and privately funded R&D stocks in the analysis. A share of the R&D stock constructed in this way consists of capital stock. We cannot distinguish in the data between a computer purchased for a researcher or one for a reception desk.

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[4] We used the Mahalanobis outlier detection procedure to identify outliers. Using critical values even more conservative than those suggested by Penny (1996) implicated the manufacture of coke and refined petroleum products, mainly because of a highly unstable price index. We have therefore excluded this manufacturing industry from our analysis (as did Eberhardt *et al.* (2013).

This leads to double-counting which can be a source of bias in our estimation of R&D returns. Fortunately, the data contains information on how much R&D spending is of an investment character, so if we assume that investment-related R&D stock is proportional to R&D investment, it is then possible to calculate the precise share of R&D stock that is also included as capital stock. We can then subtract this from the ordinary capital stock to avoid double-counting.

To evaluate the spillovers of R&D spending we construct an auxiliary variable, shared R&D stock, which weights the R&D stock in other sectors depending on their connectedness. We follow a suggestion from Eberhardt *et al.* (2013) and construct the weights based on the input-output structure of the economy. The knowledge flow can flow either from supplier to customer (forward) or the other way around (backward). We thus differentiate between these two directions of knowledge stock sharing, using weights based on supplier or customer input-output linkages.

Consider the forward-shared R&D stock at the industry $i's$ disposal that stems from industry j. We take the value of $j's$ supply to i and divide it by the overall input of industry i. By repeating this step for all the industries that supply industry i, we obtain a set of weights, by which we then multiply the respective R&D stocks. The sum is the total forward-shared R&D stock. Backward-shared knowledge stock is calculated similarly. Equation 3 shows the calculation of forward-shared R&D stock with a_{ij} being the element of an input-output matrix in the ith row and jth column.

$$forward\,shared\,R\&D\,capital\,stock = \sum_{j\neq i} w_j^j R_j,\ where\,w_j^j = \frac{a_{ij}}{\sum_j a_{aj}} \tag{2.3}$$

Table 2.1 presents the summary statistics. The effective unbalanced panel consists of 930 observations from 61 industries over 19 years. There is strong heterogeneity between sectors and over time. Private R&D spending dwarfs public spending by a ratio of four to one, while the levels of forward-shared and backward-shared capital are comparable. Some smaller industries have no R&D spending in a particular year, but these do not drive the results â€“ the results remain similar even when we omit these. Public and private R&D capital are correlated but not to such a degree that this would cause multicollinearity issues. While manufacturing is generally more R&D intense than services, public R&D support is greater, as a share of total R&D capital, in the service sector.

Table 2.1: Summary Statistics

930 observations	MEAN	SD	MIN	MAX
Value added	9,976	13,524	5	113,617
Fixed capital stock	32,377	75,079	76	836,300
Labour (FTE)	20,826	25,128	86	152,388
Private R&D expenditures	124	270	0	2,440
Public R&D expenditures	28	85	0	963
Private R&D capital	648	1,342	1	9,703
Public R&D capital	138	409	1	3,898
Private forward-shared R&D capital	514	379	32	2,278
Public forward-shared R&D capital	79	73	1	394
Private backward-shared R&D capital	423	448	21	4,354
Public backward-shared R&D capital	58	48	1	219

**All variables (except labor) are in CZK million.*
***Labour is in full time equivalent units.*

To relate R&D spending to value added, we use the Cobb-Douglas production function augmented with R&D stock as the baseline model for our analysis. We follow the notation presented by Hall *et al.* (2010) and the canonical approach of Griliches (1979):

$$Y = AL^{\beta_1} C^{\beta_2} K^{\beta_3} [K^S]^{\beta_4} e^u \tag{2.4}$$

where Y is value-added, A is the shared level of technology, L is labour input, C is capital input, K is $R\&D$ stock, and K^S is the shared knowledge pool. The coefficients β_3 and β_4 measure elasticities with respect to internal R&D stock and shared R&D stock. Taking the logarithmic transformation of the equation above, we obtain a linear model with elasticities as coefficients. Lowercase letters represent the variables after the logarithmic transformation. It is further assumed that the trend in technological development can be described by time effect λ_t and the industry heterogeneity in productivity by the industry effect μ_i.

$$y_{it} = \mu_i + \lambda_t + \beta_1 l_{it} + \beta_2 c_{it} + \beta_3 k_{it} + \beta_4 k^s_{it} + \epsilon_{it} \tag{2.5}$$

We further distinguish between private and public R&D capital and we split the shared capital stock into private/public and backward/forward varieties:

$$y_{it} = \mu_i + \lambda_t + \beta_1 l_{it} + \beta_2 c_{it} + \beta_3 private\, k_{it} + \beta_4 public\, k_{it} + \\ \beta_5 private\, k^s_{it} + \beta_6 public\, k^s_{it} + \epsilon_{it} \tag{2.6}$$

$$y_{it} = \mu_i + \lambda_t + \beta_1 l_{it} + \beta_2 c_{it} + \beta_3 private\, k_{it} + \beta_4 public\, k_{it} + \\ \beta_5 forward\, k^s_{it} + \beta_6 backward\, k^s_{it} + \epsilon_{it} \tag{2.7}$$

There are several issues with this specification. Successful industries with rising value added may increase their R&D spending, but increased R&D spending may also stimulate their value added, thus the results lack causal interpretation - the causal effect of R&D spending is likely smaller than our estimates. However, the upward bias may not be too large. Griffith *et al.* (2004) argue that because productivity is pro-cyclical, but the ratio of value added and R&D expenditures is not, the bias remains modest even in simple models without identification specification using exogenous shocks.

2.4 Econometric Estimates

Our models are estimated using fixed effects within a method for panel data, which controls for common time trend and industry-specific effects. The elasticities of R&D capital and shared R&D capital reveal the association between a 1 % increase in the respective stock and any change in value added. Although estimating R&D returns and distinguishing between financing sources, recipients and other categories could be difficult due to the collinearity of the key variables, our model does not suffer from these issues: the variance inflation factor reveals that the collinearity of the variables we use is at a permissible level (see the Appendix A.1). All the results are reported with robust standard errors, taking into account heteroscedasticity and cross-sectional correlation.

Table 2.2, column 1 presents the baseline results with aggregate R&D capital and aggregate shared R&D capital and indicates significant direct R&D returns with the elasticity of 0.04. This is in line, for instance, with the past estimates of 0.04 by Bloom *et al.* (2013) and 0.06 by Eberhardt *et al.* (2013). The indirect spillover term is also highly statistically significant with an estimated elasticity of 0.11, and again this is not substantially different from past estimates: 0.07 by Adams & Jaffe (1996), 0.09 by Wolff & Ishaq Nadiri (1993). Splitting the R&D capital along the private/public axis (column 2) shows that the direct returns are mainly driven by private spending. There is no evidence that public R&D capital has any direct link to sectoral value added. Condemning public R&D support would, however, be premature. After dividing shared R&D capital into public and private capital, it is apparent that public spending is positively associated with value added through spillovers (column 3). Interestingly, the magnitude of these spillover effects is similar for both public and private R&D stock.

Table 2.2: R&D returns and spillovers - benchmark results

Response: valued added	(1)	(2)	(3)	(4)
Fixed capital	0.270***	0.268***	0.306***	0.320***
	(0.068)	(0.069)	(0.052)	(0.051)
Labour	0.835***	0.834***	0.857***	0.857***
	(0.050)	(0.052)	(0.036)	(0.035)
R&D capital	0.040***	-	-	-
	(0.011)	-	-	-
Shared R&D capital,	0.112***	0.120***	-	-
spillover	(0.028)	(0.004)	-	-
Private R&D capital	-	0.020*	0.023**	0.022*
	-	(0.009)	(0.008)	(0.009)
Public R&D capital	-	0.003	0.005	0.005
	-	(0.004)	(0.004)	(0.005)
Private shared R&D capital,	-	-	0.078**	-
spillover	-	-	(0.028)	-
Public shared R&D capital,	-	-	0.118***	-
spillover	-	-	(0.029)	-
Backward-shared R&D capital,	-	-	-	0.039*
spillover	-	-	-	(0.016)
Forward-shared R&D capital,	-	-	-	0.070**
spillover	-	-	-	(0.024)
Adjusted R-squared	0.530	0.530	0.540	0.542
Fixed effects (years)	Yes	Yes	Yes	Yes
Fixed effects (industries)	Yes	Yes	Yes	Yes
Number of observations	930	930	930	930

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Dividing the shared R&D capital stock based on forward and backward linkages of the industries (column 4) shows that spillovers happen in both directions. However, spillovers from supplier to consumer seem to be more prominent. This serves as evidence for the presence of knowledge spillovers, given that rent spillovers are more likely to happen in the backward direction.

Splitting the spillover term even further, into public/private in both directions would be even more revealing but, unfortunately, collinearity issues make such an estimation unreliable.

Next, we examine non-linearity in R&D returns. We use threshold regression models to inspect potential discontinuity in R&D returns. It is likely that once R&D capital reaches a certain critical mass, its effect changes. Criscuolo *et al.* (2005) uses the example of drug development to highlight the need for large amount of human and financial resources in large-scale research activities. We thus hypothesize that when the investment reaches such a critical mass, returns to R&D capital increase. Following Fong *et al.* (2017), we estimate the change points based on the exact method where the estimated change point is chosen from a grid based on the likelihood of the final estimation. Figure 1 shows the likelihood distribution of the change points in private R&D capital stock. The distribution suggests there is indeed a critical value beyond which the returns to R&D tend to be linear. The procedure of Fong *et al.* (2017) showed that the chosen change point is indeed statistically significant (with p-value of 0.004), but it did not identify a statistically significant change point in public R&D capital stock.

We continue with a segmented threshold regression which estimates a linear relationship between the dependent variable and the threshold variable both below and above the threshold. This is equivalent to the standard estimation if we let the independent variable of interest interact with a dummy which is equal to one when the values of the particular independent variable are greater than the estimated threshold. The interpretation is then analogical to any model with interaction terms.

Table 2.3 below provides threshold regression estimates for both private (columns 1 and 2) and public (columns 3 and 4) returns to R&D capital. The segmented threshold models show that there is a certain critical level of private R&D capital beyond which the returns are substantial. This is in line with the notion of there being a critical mass of R&D capabilities that firms need to generate in order to profit from their R&D activities (de Meyer & Mizushima 1989). Our estimation does not detect any such critical mass in public R&D capital which is in line with the not statistically significant change point. Distinguishing between public and private shared R&D stock or forward and backward shared R&D stock does not affect the results - we find no evidence of non-linearity in those variables.

Lucking *et al.* (2018) inspected whether returns to R&D remain stable in

Table 2.3: R&D returns and spillovers - threshold models

Response: valued added	(1)	(2)	(3)	(4)
Fixed capital	0.254***	0.261***	0.270***	0.277***
	(0.070)	(0.071)	(0.070)	(0.071)
Labour	0.841***	0.845***	0.819***	0.822***
	(0.068)	(0.058)	(0.068)	(0.066)
Private R&D capital	0.005	0.001	0.028***	0.028**
	(0.014)	(0.014)	(0.012)	(0.012)
Public R&D capital	0.000	-0.000	-0.013	-0.012
	(0.006)	(0.006)	(0.013)	(0.012)
Private shared R&D capital,	-0.001	-	-0.003	-
spillover	(0.001)	-	(0.003)	-
Public shared R&D capital,	0.049***	-	0.041**	-
spillover	(0.019)	-	(0.019)	-
Backward-shared R&D capital,	-	-0.001	-	-0.003
spillover	-	(0.001)	-	(0.003)
Forward-shared R&D capital,	-	0.061***	-	0.053**
spillover	-	(0.022)	-	(0.023)
Private R&D capital, threshold	0.17***	0.17***	-	-
	(0.05)	(0.05)	-	-
Public R&D capital, threshold	-	-	0.019	0.018
	-	-	(0.045)	(0.044)
Adjusted R-squared	0.530	0.530	0.530	0.530
Fixed effects (years)	Yes	Yes	Yes	Yes
Fixed effects (industries)	Yes	Yes	Yes	Yes
Number of observations	930	930	930	930

**** p<0.01, ** p<0.05, * p<0.1*

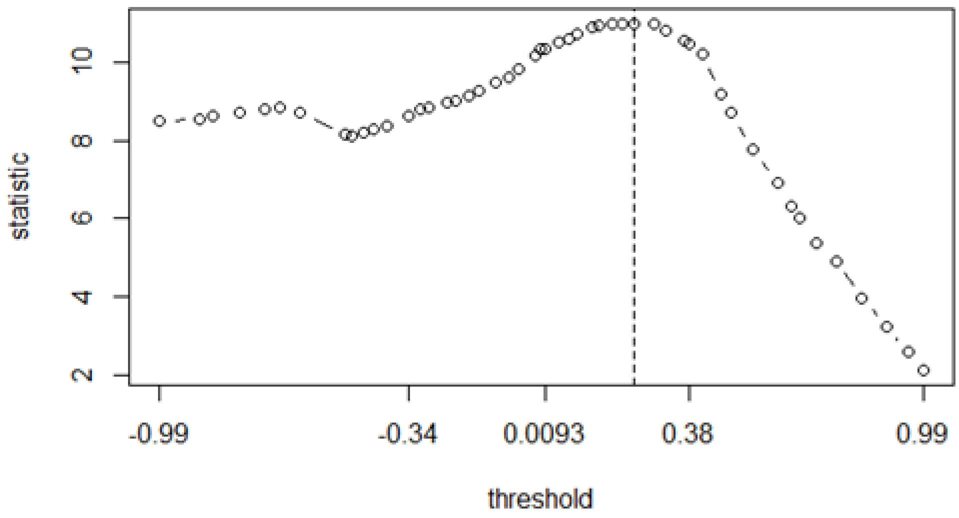

Figure 2.1: Maximum likelihood distribution of change points, private R&D capital stock

time and found that they hardly changed between 1985 and 2015. Their approach was to let the variables interact with dummies reflecting 5-year periods, so as to inspect the general development of R&D returns in time. We are interested in a more specific time question: whether the returns were affected by the great financial crisis. We therefore interact our measures of R&D capital with a dummy capturing the period from 2009 onward, as the crisis hit the Czech economy in 2009.

Table 2.4 provides the results. As the crisis hit, firms were likely tempted to curb private R&D investment in response to their falling revenue. The results indicate, however, that those who managed to maintain their R&D spending benefitted handsomely as it extended their lead over their competitors (column 1). The returns to private R&D in the years 2009-2015 were more than twice as big as those in 1996-2008.

Public R&D spending is not positively associated with sectoral performance during the crisis. This can be explained by R&D support having been used as an immediate fiscal stimulus when the crisis hit. With other tools for government support not yet in place, public R&D spending might have been streamed to the struggling industries in order to keep them afloat. Accordingly, the direct returns to public R&D spending are estimated to be essentially zero in pre-crisis years but turn sharply negative in 2009. This drop in returns to public R&D is in line with Hud & Hussinger (2015), although they did find a small positive effect. The spillovers - divided into public/private (column 1) or

Table 2.4: R&D returns and spillovers - the effects of the economic crisis

Response: valued added	(1)	(2)
Fixed capital	0.306***	0.306***
	(0.052)	(0.053)
Labour	0.875***	0.881***
	(0.036)	(0.036)
Private R&D capital	0.020**	0.020*
	(0.010)	(0.010)
Public R&D capital	-0.006	0.005
	(0.009)	(0.005)
Private shared R&D capital, spillover	0.032	-
	(0.019)	-
Public shared R&D capital, spillover	0.075***	-
	(0.022)	-
Private R&D capital x	0.043***	0.045***
period (2009-2015)	(0.013)	(0.013)
Public R&D capital x	-0.041***	-0.045***
period (2009-2015)	(0.013)	(0.013)
Private shared R&D capital x	-0.063	-
period (2009-2015)	(0.039)	-
Public shared R&D capital x	0.056	-
period (2009-2015)	(0.031)	-
Backward-shared R&D capital,	-	0.039*
spillover	-	(0.017)
Forward-shared R&D capital,	-	0.075***
spillover	-	(0.025)
Backward-shared R&D capital x	-	0.007
period (2009-2015)	-	(0.020)
Forward-shared R&D capital x	-	-0.078
period (2009-2015)	-	(0.020)
Adjusted R-squared	0.555	0.559
Fixed effects (years)	Yes	Yes
Fixed effects (industries)	Yes	Yes
Number of observations	930	930

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

forward/backward (column 2) - were not, however, affected by the crisis.

2.5 Conclusion

In this paper, we have analyzed direct and spillover returns to R&D in Czechia. While direct returns only come from private R&D spending, spillover effects are driven by both privately and publicly funded R&D and happen both forwards and backwards in the production process. The great financial crisis increased direct returns to private R&D funding and decreased direct returns to public R&D funding, widening the gap in direct returns.

Our results are mainly explorative: no claim of causality can be made using our specification. Successful industries may invest in R&D with visions of further growth, while struggling industries may rather restrict their R&D investment to improve their cash flow. The cause-effect direction between value added and R&D investment would then be the opposite of that usually suggested. This means that the R&D returns we have presented here are likely overestimated. However, as we have mentioned, this upward bias is likely small (see Griffith *et al.* (2004)). Another source of upward bias in our estimates of direct R&D returns are spillovers between firms within the same industry; these are not considered in our industry analysis and are thus counted as direct returns. While this is a serious matter, it should not be overstated: our results do not differ substantially from those presented in studies that used firm-level data (Hall *et al.* 2010; Rogers 2010). Lastly, it is difficult to distinguish between true technology spillovers resulting from public R&D spending and mere rent spillovers. However, by splitting the shared public R&D capital into forward and backward directions, we show that technology spillovers are likely far more substantial than rent spillovers.

Despite these various shortcomings, our results largely confirm the common intuition as to the benefits of R&D spending, with positive and significant direct and spillover R&D returns (with the exception of direct returns to public spending). The absence of a positive direct return to public R&D support shows that intra-industry spillovers â€“ which would also be captured by the direct effect â€“ are indiscernible. Assessments of public R&D support should thus not be limited to institutionsâ€™ immediate industry partners: the spillover effects of public investment in R&D are likely far-reaching and may materialize in other industries over longer periods of time.

The direct effects of R&D spending are not linear, and this fact should be taken into account in R&D-enhancing policies. More specific research is needed to establish how policies should be adjusted to these phenomena. Ideally, a proper impact assessment involving different groups of stakeholders must be conducted before any policy is implemented. Such assessments should be based both on industry data and microdata. The results presented in this paper are generalizable only at the industry level. Using firm-level data would provide complementary evidence and map the Czech R&D landscape in greater detail. With increasing data availability, such a study will hopefully be possible in the near future. Granular data could help us identify causal effects, show how returns to public R&D differ based on sources of financing (regional, state, EU funds), and uncover synergies in distinct R&D projects.

Chapter 3

Who Benefits from Global Value Chain Participation? Does Functional Specialization Matter?

3.1 Introduction

Global value chains (GVC) have integrated economies into global and complex production chains that offer new opportunities for upgrading (Kummritz *et al.* 2017). Knowledge spillovers and network effects have been shown to positively influence productivity (Frohm & Gunnella 2017). However, GVC participation does not distribute its gains evenly across the board, even though the value added of the chain as a whole rise (Gereffi & Fernandez-Stark 2016).

The past few decades have been marked by the integration of developing countries into the world economy at an unprecedented pace (World Bank, 2016) and this phenomenon raises questions about the heterogeneity of GVC participation. Kummritz (2015) showed that the effects of GVC participation are different for low and high-wage countries, with the latter benefiting more. Fagerberg *et al.* (2018) confirmed that countries with low capabilities appear to be particularly disadvantaged in this regard. These insights are not only relevant for developing countries: differences in technological development are also present among industries in the developed world.

This paper contributes to this line of research by exploring the heterogeneity of GVC effects in a novel and more detailed way. Using proxies for GVC participation and functional specialization, based on data from the World Input-Output Database (WIOD) and function specialization data collected by Timmer *et al.* (2019) on 35 industries in 40 countries during the period 2000-2011, we show that the benefits of GVC participation depend on the participants' functional specialization as well as the functional specialization of their GVC partners. Our results indicate that fabrication-focused industries profit from GVC participation more than industries specialized in other business functions and that this is largely because of their engagement with R&D-oriented GVC partners. Grouping countries according to their levels of economic development shows that GVC participation with R&D-oriented industries benefits low-developed countries the most and that fabrication-related GVC participation benefits those countries the least.

We aim to bridge two strands literature regarding GVCs: rather qualitative papers with strong foundations in management theory (e.g. Gereffi *et al.* (2005); Ernst & Kim (2002)) and empirical, exploratory works which make us of newly available data such as WIOD or firm-level data (e.g. Stöllinger (2021); Timmer *et al.* (2019); Baldwin *et al.* (2014). These two strands have, to our belief, developed mostly independently, to the detriment of understanding the consequences GVCs have on distinct actors of the world economy.

Although we are careful not to make any inferences about causality, this paper's results reveal where the benefits of GVC participation tend to be concentrated. These results call for a more nuanced view of the potential benefits of GVC participation and highlight the fact that latecomers to GVCs are in a significantly different position from those who run the show. National governments, as well as major international organizations, should take note that GVC participation effects are not uniform across all countries and industries and that they depend on the structure of the particular GVC. Some development policies should be adjusted in the light of these findings. The bottom line is functional specialization makes a difference to where the benefits of deepening globalization are felt.

The rest of the paper is structured as follows: section 2 introduces the theory, explains the key concepts, and formulates hypotheses; section 3 describes the data and methods; section 4 presents the empirical results and section 5 concludes.

3.2 Theory, concepts, and hypotheses

Trade theories were long focused primarily on trade in final goods, with the market the only exchange platform considered. With rapidly decreasing transaction and communication costs driven by advancing technology, however, more elaborate structures that are very different from the simple exporter-importer relation have proliferated. Production has increasingly been sliced into individual tasks which come together to make up a final product. The concept of trade in final goods has thus given way to the idea of trade in tasks (Grossman & Rossi-Hansberg 2008). Trading tasks requires a greater degree of coordination, and so hierarchical models other than purely market-based models were adopted (Gereffi *et al.* 2005). GVC analysis focuses specifically on how the production process is sliced up and on the non-market interactions that this division produces.

This does not mean that classic trade theories are irrelevant. Countries do still exchange goods based on their relative competitive advantage (Ricardo, 1817), and they specialize in production intensive in their abundant factor (Heckscher 1919; Ohlin 1935). GVCs, like trade, are shaped by geographical and cultural proximity: firms naturally seek interactions with low transaction costs, both in terms of transportation and communication (Ernst, 2002). This long resulted in a rather limited set of potential trading partners. However, as advances in technology and the removal of legal obstacles decrease transaction costs, new trade opportunities arise all over the world (Seuring & MĂĽller, 2007).

Analyzing GVCs rather than just trade gives us the opportunity to study the non-market relations between participants. The benefits of GVC participation are - with the exception of economic gains caused by knowledge transfer, spillovers, and specialization - driven by participantsâ€™ positions within the hierarchy of the GVC (Kaplinsky 2000). It well might be that those GVC participants who occupy prominent positions in the GVC hierarchy in terms of their tasks and specialization within the GVC benefit more from the GVC than the rest. That is what we are interested in exploring in this paper.

3.2.1 Heterogeneity in the effects of GVC participation

Engaging firms with distinct capabilities in a GVC does not benefit all the firms in that GVC equally. The logic of technology gains suggests that firms with fewer capabilities will benefit the most from inter-firm cooperation (Blalock & Gertler 2009), but this narrative misses a crucial reality. Firms with rare capabilities that offshore or outsource routine production tasks to other firms experience gains that cannot be explained in terms of technology improvements

(Lee & Gereffi 2015). This is made possible due to the uneven distribution of value added across the production process, described by the smiling curve. The firms that dominate a particular GVC can influence its architecture and position themselves in the GVC stages associated with the greatest value added, as they essentially govern the GVC. Consequently, firms with fewer capabilities are left responsible for tasks that are linked with very little value added.

Possessing demanded and rare capabilities is not only beneficial because the market rewards it. Capability disparity within a GVC defines its hierarchy and the value added distribution. Gereffi *et al.* (2005) identify five forms of GVC governance that largely depend on the capability disparity between the participating firms. When the disparity is high, companies form rigid hierarchical structures and shift a portion of their inter-firm interactions outside the market. When there is no capability disparity and there is no need for explicit coordination, GVCs are governed by the market. GVC participation thus does not only lead to technology transfer and specialization opportunities, but it also determines how much a firm can profit thanks to its hierarchical standing relative to its GVC partners.[1]

Relative capabilities can be observed even at the country or industry level using functional specialization. Using FDI data, Stöllinger (2019) shows that different countries focus on different business functions with richer countries like Germany and the UK focused on R&D and logistics and relatively poorer countries like Slovakia and Poland being active mainly in fabrication. Looking at industry-level data, Meng et al. (2020) reveal a similar pattern: industries far and close to the customer get a greater share of the final price than those in the middle. Another take is to measure upstreamness (Antràs *et al.* 2012), i.e., the distance from the final customer, and relate this measure to economic performance. Descriptive analysis of Hagemejer & Ghodsi (2017) shows that despite the convergence of the new EU member states, they remained surprisingly upstream â€“ they merely focused more on intermediate products. The relationship between this structural change and value added, however, remains opaque.

Such value added distribution along the stages of production is very similar to the “smile curve” we observe at the firm level. The lesson from firm-level data is thus transferable to the whole economy with a strong implication of

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[1] Dominant firms have many opportunities to exert power within their GVC. One example is management of working capital: the dominant link in the GVC can force others to accept their preferred payment calendars (Kaplinsky 2000).

functional specialization. Functional specialization and specialization in production stages are two distinct concepts, yet they often used interchangeably when moving from the firm (Rungi & Del Prete 2018) to the economy-wide perspective (e.g. Mudambi (2008). Stöllinger (2021) shows that the shape of the economy-wide smile curve is indeed similar to the firm-level curve, and Baldwin *et al.* (2014) provide evidence that it has become even curvier in recent years, with the service sector gradually increasing its value added share at the expense of manufacturing. The assumption made in this paper is that R&D business functions come as one of the first stages of production, whereas the marketing business function comes as the last. At the macro-level, it thus makes little difference whether we refer to functional specialization or specialization in production. What matters is the rare capabilities contained in those functions which define the hierarchy of the value chain and its value added distribution.

To increase one's value added, one can either improve the productivity of the current tasks or move to the part of the value chain with greater value added. Humphrey & Schmitz (2002) call these two channels process upgrading and functional upgrading, respectively. Competent GVC partners can serve as sources of new technology improving efficiency. Ernst & Kim (2002) posit that GVCs can serve as a knowledge conduit between heterogeneous firms, both through the market (FDI, trade, and machinery) or through informal channels (technical standards, imitation). Saia *et al.* (2015) empirically support this claim by showing that international connectedness ensures contact with the global technology frontier and such contact positively influences the productivity of all engaged agents.

Process upgrading leads to capability formation (Ernst & Kim 2002), so a firm can acquire capabilities in stages with little value added and use them for subsequent functional upgrading. But functional upgrading is more difficult and is likely to meet with resistance from other players in the GVC as they protect their market share (Lee & Gereffi 2015). This is of special importance for developing economies. Fagerberg *et al.* (2018), for example, find no evidence of GVC participation being linked to better economic performance, and on the contrary show that countries with underdeveloped capabilities may even suffer from GVC participation. It is possible that the technology gains GVC participation facilitates can be offset by unfavorable positioning within the GVC hierarchy.

This paper investigates the association between value added, functional specialization, and GVC participation. It is beyond its scope to discern functional upgrading as its dynamic nature is difficult to capture, but we hope to find evidence for process upgrading being related to a certain kind of GVC participation. Fabrication, more than any other specialization, requires GVC participation to be productive, as manufacturing value chains became increasingly complex, interconnected, and global over the last decades (Timmer *et al.* 2014). For an industry focusing on fabrication, staying out of the realm of GVCs, either up or down the value chain without access to relevant foreign suppliers or customers, respectively, is not likely to be a viable winning strategy anymore. Process upgrading is largely facilitated by a dominant GVC player in traditional industries focusing on fabrication (Pietrobelli & Rabellotti 2004). Moreover, GVC participation is expected to induce process upgrading mainly through knowledge transfer. Knowledge, in turn, is transferable the easiest in a codifiable form (Hall 2006). As the proportion of codifiable to tacit knowledge is the greatest in fabrication as opposed to other business functions, such as marketing, fabrication-oriented industries are better suited to benefit the most from GVC participation.

Hypothesis 1. Increasing GVC participation benefits more fabrication-oriented industries.

The global production networks exploit the ex-ante prospects of the respective comparative advantages, but once they are in place, new opportunities arise from the very structure of the networks. Not only is the existing technology diffused along supply chains (MacDuffie & Helper, 1997), but new systems are also used specifically for developing new technologies and disseminating them immediately within the network (Dyer & Nobeoka, 2000). The perspective of the fabrication-oriented industry is then enriched by distinguishing with what sort of other industries GVC participation happens. GVC participation leads to knowledge spillovers but that is likely to happen only across certain kinds of business functions such as R&D.

Hypothesis 2. Fabrication-oriented industries benefit disproportionately from GVC integration with R&D-focused peers.

It is not clear whether the power architecture follows the division between developed and developing countries. Horner & Nadvi (2018) claim that the notion of firms from the developed world dully outsourcing and offshoring their low-value-added activities to developing countries is outdated. GVC participation within the global South is on the rise and so are the capabilities of the engaged participants. Taking this argument to the extreme, we should observe the same effects from GVC participation no matter whether we look at GVC participation within the developed world, the developing world, or across the globe. What matters is only the specialization within the chain. Any remaining heterogeneity can be attributed to factors such as favorable path dependency, institutional quality, and human capital (Zhou 2018).

Hypothesis 3. High-developed countries do not reap disproportionate benefits from GVC participation.

GVCs are traditionally thought of as covering most of the production process, from design and extraction of raw materials to sales and marketing. Such GVCs are structurally different from those that are within a single industry. For instance, collaboration between firms in the automotive industry requires greater cooperation than collaboration between the mining and smelting industries. Shorter, single-industry GVCs have proliferated in the past few decades as production has become more fragmented (Wakasugi 2007).

As a result, we investigate whether GVC participation within a single industry has a distinct effect. Technological proximity offers greater opportunities for technology spillovers, but the need for intense coordination may result in tight hierarchical structures (Gereffi *et al.* 2005). The effects of technology spillovers and GVC hierarchy in intra-industry GVCs are intensified by foreign direct investment, which is particularly common within industry and is also associated with gains in value added (Liu *et al.* 2000). Controlling for functional specialization, intra-industry GVCs thus should provide more benefits than inter-industry ones.

Hypothesis 4. Increases in intra-industry GVC participation benefit the industries more than increases in regular GVC participation.

3.2.2 Empirical approaches to GVC analysis

The empirical research on GVCs has gained prominence in the last two decades. It builds on international trade statistics, customs statistics, and input-output tables (Amador & Cabral 2016). The input-output approach we follow in this study was pioneered by Feenstra & Hanson (1996; 1999) who introduced a measure of foreign share in domestic production and so turned their attention to the global integration of production networks. Hummels *et al.* (2001) took this even further with their concept of vertical specialization, which describes production located in at least two countries and goods crossing borders at least twice.

As novel and useful as this approach was, it neglected possible discrepancies in value added at each stage of production and circular aspects of production. A new value-added approach by Johnson & Noguera (2012), building on Hummels *et al.* (2001), accounted for the possibility of exporting intermediate goods that are later part of imported final goods by introducing the value added share of gross exports. This improved estimates of bilateral trade quite significantly. The method was later formalized by Koopman *et al.* (2014) so that gross exports can be easily broken down into value added flows by matrix formulation.

Los *et al.* (2015) introduced yet another metric to measure international fragmentation. Building on Feenstra & Hanson (1999), they present the foreign value-added share, which accounts for the inter-industry circular flow of goods and avoids double-counting, similarly to Johnson & Noguera (2012). This measure enables researchers to investigate GVC participation within a single country or region or indeed on a global scale. It is thus suitable for detailed GVC analysis, as it can be sliced and diced at will, and has indeed been used extensively in recent empirical papers (see Blanchard *et al.* (2016) or Wolszczak-Derlacz & Parteka (2018). Specifically, Timmer *et al.* (2014) provide a detailed analysis of the development of GVC participation over time and of the way GVC participation affects capital and labor shares. Los *et al.* (2015), building on this work, show that although many GVCs are clustered within regions, the truly global ones have progressed far more than the regional ones.

Notwithstanding the convincing results, the methods used in this strand of research are not clear of criticism. Nomaler & Verspagen (2014) argue that this type of aggregated input-output analysis is significantly distorted. The aggregate nature of the input-output means that intra-industry circular flows are ignored. Take the manufacturing of the electrical equipment industry as an example: undoubtedly, electrical equipment is an input to this industry. This value added is lost in the aggregation because it happens within the same sector. Also, value-added-to-output ratios, which are used extensively when computing measures such as foreign value added depend on the GVC stage. The ratios in later stages are smaller as the gross output is greater, which in turn overestimates the contribution to value added from sectors engaged in the last stages of production.

Another issue is the very nature of the input-output data. Because the original data is the supply and use tables which are infrequent, its longitudinal dimension is obtained using an estimation method (Temurshoev & Timmer 2011). Such a procedure exploits data from National Accounts Statistics and comes up with harmonized, comparable time series. Despite the method's quality, one can still argue that the data are not direct observation which can skew its analysis. Unfortunately, to our knowledge, no remedy exists at the moment.

3.3 Data and methods

Our analysis is based on data from the World Input-Output Database (Timmer *et al.* 2015). Release 2016 provides a panel of 54 industries in 43 countries over the period 2000-2014. We use input-output tables to calculate foreign value added share measures (FVAS) and socio-economic accounts for value added, capital, and labor employed. All the currencies are converted to US dollars and use 2010 prices. For the FVAS calculation, we closely follow Los *et al.* (2015). FVAS reveals how much of the total value added of the particular GVC is produced abroad - a measure of international integration. Based on the input-output tables, it is calculated in the following way:

$$FVAS(c,j) = \frac{\sum_{k \neq j} VA(k)(c,j)}{\sum_k VA(k)(c,j)} \tag{3.1}$$

where VA stands for value added, c for the country, j for the industry, k for the GVC partner. The value added created in each industry within each country is given by the vector $\mathbf{h}$:

$$\mathbf{g} = \hat{\mathbf{v}}(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}(\mathbf{Fe}) \tag{3.2}$$

In this equation, $\hat{\mathbf{v}}$ is a matrix with value added over gross output on its diagonal, $(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}$ is the standard Leontief inverse, $\mathbf{F}$ is the matrix of the final output, and $\mathbf{e}$ is the summation vector. The choice of matrix $\mathbf{F}$ determines which value chain we consider. For each industry-country pair, we thus have a vector of value added produced in each of the other pairs which adds up to the gross output. In other words, the vector shows the income shares of each industry's final product in all country-industry pairs. Such vectors can then be sliced and diced at will.

We use data on business functions assembled by Timmer *et al.* (2019). The dataset provides information on workers' income shares for fabrication, R&D, marketing, and management. The dataset spans across 35 industries, 40 countries over years 1999-2011. Merging this dataset with WIOD , we can relate functional specialization with GVC participation, specifically FVAS. This enables us to determine the FVAS related to certain business function. For instance, we calculate how much FVAS of each industry comes from fabrication by multiplying the particular FVAS value with the fabrication share in that industry. The equation below shows the calculation of FVAS related to fabrication in country c, industry j, where $FS_{d,j}^{FAB}$ is fabrication functional specialization in country d, industry j, and $VA_{d,j}(c,i)$ is the value added produced in country d, industry j for the final product of country c, industry i.

$$FAB\;FVAS(c,i) = \frac{\sum_{d \neq c,j} FS_{d,j}^{FAB} VA_{d,j}(c,i)}{\sum_{d,j} VA_{d,j}(c,i)} \tag{3.3}$$

The same procedure is used to calculate FVAS related to R&D and marketing functional specialization. The business functions measure the relative intensities so they all add up to 1. Increasing specialization in R&D is always offset by decreasing specialization in the remaining business functions. We drop management business function[2] because we want the functional specialization to reflect the specialization in production stages as closely as possible. Since management is necessary for every stage of production, it cuts across the relevant categories.[3] Slicing the FVAS in this way provides additional insights into how the heterogeneity of a GVC affects value added. Table 3.1 below provides the summary statistics of the key variables. The panel is unbalanced because a few industries in a few countries are missing in the dataset. The statistics are computed across time, industry, and country dimensions, i.e., pooling the data.

We base our estimation on the Cobb-Douglas production function where technology (A) is assumed to be a function of foreign value added share and the relative intra-industry productivity. As such, this specification is similar to Kummritz *et al.* (2017) - we use value added as the dependent variable because it captures changes in productivity as well as changes in factor utilization as

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[2] Dropping management, we rescale the rest income shares so that they add up to one without management.

[3] Management business function includes not only top management but also middle management positions and even shop floor production managers, i.e., professions such as production and operations manager or manager of research and development. In addition, the management business function comprises professions such as legislators and government officials which have been probably difficult to place elsewhere. Hence, this seems to be rather a residual category from the production stages perspective.

Table 3.1: Summary Statistics

	N	MEAN	SD	MIN	MAX
Capital stock (USD millions)	23,023	1,075	7,134	0	183,308
Labor (FTE)	23,023	384	1,336	0	24,966
Value Added (USD millions)	23,023	351	1,174	0	21,379
R&D Business Function	23,023	0.181	0.15	0	1
Fabrication Business Function	23,023	0.315	0.253	0	1
Marketing Business Function	23,023	0.341	0.217	0	1
FVAS total	23,023	0.209	0.16	0	0.936
o/w FVAS related to R&D	23,023	0.035	0.03	0	0.27
FVAS related to Fabrication	23,023	0.066	0.061	0	0.37
FVAS related to Marketing	23,023	0.07	0.056	0	0.431

Source: Author's computations

well as gross profits of firms and workers' wages. The aim is to exploratively relate GVC participation and functional specialization to value added and try to control for the omitted variables by an extensive fixed effects structure. The basis of our estimation lies in the general production function:

$$Y(A,F) = A(FVAS, ...)F(K,L) \tag{3.4}$$

Logarithmic transformation provides the usual regression equation:

$$\begin{aligned} y_{cjt} = A_{cj} + \beta_1 FVAS_c jt + \beta_2 k_{cjt} + \beta_3 l_{cjt} + \beta_4 RND_{cjt} + \\ \beta_4 FAB_{cjt} + \beta_4 MAR_{cjt} + \lambda_t + u_{cjt} \end{aligned} \tag{3.5}$$

where y is the logarithm of value added, A is a constant describing the level of employed technology (country-industry fixed effects), $FVAS$ is the foreign value added share, k is a logarithm of nominal capital stock, l is a logarithm of total hours worked, RND, FAB, and MAR are the income shares for the respective business function, and λ represents the common time dummies. The subscripts c, j, t stand for country, industry, and year, respectively.

Adding the three business functions, we aim to investigate the distribution of value added along the production stages. The empirical literature shows, that the value added is the lowest in the fabrication stage Rungi & Del Prete (2018). To test hypotheses 1, we thus let our measure of GVC participation, FVAS, interact with fabrication business function. This tells us, whether the distribution curve flattens as the result of GVC participation or whether it curves even more. In other words, the positive interaction would suggest that GVC participation results in process upgrading beneficial to fabrication-oriented industries. The potential omitted variable bias is mitigated by the country-industry and time fixed effects. Different levels of productivity between the sectors as well as the development and common shocks are accounted for by the dummy structures employed in the estimation.

To test the second hypothesis, FVAS is split into that related to fabrication, R&D, and marketing:

$$\begin{gathered} y_{cjt} = A_{cj} + \beta_1 RND_{cjt} + \beta_2 FAB_{cjt} + \beta_3 MAR_{cjt} + \beta_4 RND\_FVAS_{cjt} + \\ \beta_5 FAB\_FVAS_{cjt} + \beta_6 MAR\_FVAS_{cjt} + \beta_7 k_{cjt} + \beta_8 l_{cjt} + \lambda_t + u_{cjt} \end{gathered} \tag{3.6}$$

Once again letting the fabrication business function interact with the now split FVAS shows how different kinds of GVC participation are related to the value-added distribution along the production stages. If the interaction term is positive, it is a piece of evidence for the specific GVC participation helping fabrication-oriented industries in process upgrading, possibly through knowledge transfer. For instance, we would expect that this effect is especially pronounced when participating in GVCs with R&D-oriented partners. To the best of my knowledge, GVC participation effects have not previously been examined in this way.

To test the third hypothesis about country heterogeneity, we split the countries into three groups of low-developed, medium-developed, and high-developed according to their overall level of economic development. The high-developed group consists of Western countries, Japan, Korea, and Taiwan. Countries from Southern Europe and most post-communist countries form the medium-developed group and the remaining countries are included in the low-developed group. This division is based on that of the World Bank (2019), where our low-developed group mirrors the lower and upper middle income groups. We further divide the high income group of the World Bank according to the income per capita so that we can inspect the differences between different levels of development among the high-income countries. For instance, Germany and Poland both belong to the high income group, but their roles in global value chains are indisputably different. See Appendix A1 for detailed composition of the country groups.

Table 3.2 breaks down the summary statistics according to the country

Table 3.2: Mean values of GVC participation related to specific business functions, by country development group, weighted by industry value added

	Low-developed	Medium-developed	High-developed
R&D business function	0.151	0.189	0.206
Fabrication business function	0.344	0.261	0.228
Marketing business function	0.347	0.389	0.411
FVAS total	0.183	0.232	0.209
o/w FVAS related to R&D	0.031	0.042	0.043
FVAS related to fabrication	0.087	0.098	0.080
FVAS related to marketing	0.065	0.092	0.086

Source: Author's computations

groups. R&D and marketing business functions gain importance with rising country development and the opposite is true for fabrication business function. This corresponds with the findings of Stollinger (2019). The average general GVC participation (FVAS) is similar across the country groups but splitting it reveals a pattern. Low-developed countries are less integrated with R&D-oriented and marketing-oriented GVCs. This suggests low-developed countries are mainly active in manufacturing industries as suppliers. Medium-developed countries are even more participating in fabrication-focused GVCs, but this composition shifts over time as Table 3.3 shows. Their participation in R&D and marketing-oriented GVCs is on par with high-developed countries.

FVAS rose over time for all three development groups (Table 3.3). This is consistent with the evidence from Los et al. (2015) and World Bank Group (2017). Only during the great financial crisis did global economic integration experience a drop. The kind of deepening GVC participation was, however, different between the development groups. All country groups increased their GVC participation related to marketing. But whereas low-developed countries raised their fabrication-oriented GVC participation, the remaining groups focused instead on GVC participation related to R&D. This is best vindicated by countries like Czechia which participates heavily in GVCs dominated by German multinationals concentrating on R&D and marketing. R&D-focused GVC participation is likely the source of knowledge spillovers (as will be examined further), but it Is likely the already developed countries which, due to their composition of GVC participation, benefit the most.

The differences between country group business functions also do not stay constant over time. Only the share of fabrication is diminishing roughly evenly across the country groups. R&D business function, on the other hand, is gaining importance solely in medium and high-developed countries. Marketing business function strengthens everywhere, but the increase is most prevalent in low-developed countries. The rising importance of R&D business function in high-developed countries hints at the possibility of knowledge spillovers from those countries to the less-developed ones, especially with the R&D-related GVC participation soaring.

Table 3.3: Change in business functions and GVC participation related to specific business functions in country development groups between 2000 and 2011

	Low-developed	Medium-developed	High-developed
Δ R&D business function	-0.005	0.018	0.028
Δ Fabrication business function	-0.034	-0.051	-0.044
Δ Marketing business function	0.024	0.008	0.004
Δ FVAS total	0.028	0.028	0.035
o/w Δ FVAS related to R&D	0.006	0.010	0.013
Δ FVAS related to Fabrication	0.010	0.004	0.006
Δ FVAS related to Marketing	0.012	0.014	0.016

Source: Author's computations

3.4 Econometric Results

We use the standard approach of demeaning variables using the within transformation. The country-industry fixed effects are thus implicitly present in the model. The variables in interactions are centered, so that the interactions have clearer interpretation. We further add the time effects to control for the common time development and country-industry effects to account for any additional individual effects. In all the regression results we present clustered standard errors. The estimated coefficients thus describe the association of a unit increase in GVC participation with a percentage change in value added. The different levels of GVC participation are controlled for by fixed effects. Admittedly, this specification does not identify any causal effect of GVC participation on value added. Growing industries may increasingly participate in

GVCs while GVC participation may bring about more value added. To identify a causal effect, however, we would need an exogenous shock, which is difficult to find in this context. This paper thus offers only an explorative analysis pointing to potential causal links, without directly inferring causality.[4]

3.4.1 GVC participation and value added

Table 3.4 presents the benchmark results. In column 1, the total FVAS has a positive impact on value added, irrespective of the trading partner and its functional specialization within the value chain. This is in line with Kordalska *et al.* (2016).[5] Adding functional specialization of the industry using the intensity of R&D, fabrication, and marketing business functions, column 2 hints that the industries focusing on marketing produce relatively less value added holding the other factors of production constant. This is somewhat surprising considering the industry-level smiling curve. However, as Rehnberg & Ponte (2018) show, the distribution of value added is, at the industry level, rather of a smirk shape, so the drop in the final production stage becomes somewhat less shocking. The results do not change when both GVC participation and functional specialization are considered (column 3).

As we hypothesize that GVC participation should also link to value added through functional specialization, we let it interact with the fabrication business function. Results in column 4 show that fabrication specialization is profitable only if it is accompanied by sufficient GVC participation. Isolated manufacturing industries seem to lag behind those who form the fabric of the GVCs.

However, such an approach neglects the FVAS composition. Distinguishing between R&D-related and fabrication-related GVC participation uncovers heterogeneity of the interplay between GVC participation and value added. The results in column 1 of Table 3.5 show that the perks of GVC participation are considerably lower in the case of marketing-related links. An alternative

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[4] Using covariates distinct from GVC participation (yet linked to it), such as foreign direct investment, would make these estimates more precise. But merging the WIOD dataset with another dataset would mean losing observations which, we believe, is not feasible as the aim is to cover as many countries and industries as possible to get the utmost precise picture of the interlinkages in the world economy. However, fixed effects partially mitigate the omitted variable bias.

[5] However, Kordalska et al. use foreign value added as the independent variable, whereas this study uses foreign value added share. This study is primarily interested in how relative GVC participation affects productivity. Rising overall foreign value added does not say much about the effects of GVC participation intensity. FVAS, contrarily, captures directly how much of the total value added is contributed by different foreign partners.

Table 3.4: Benchmark results

	(1)	(2)	(3)	(4)
Capital	0.57***	0.57***	0.57***	0.56***
	(0.01)	(0.01)	(0.01)	(0.01)
Labor	0.26***	0.25***	0.25***	0.25***
	(0.01)	(0.01)	(0.01)	(0.01)
FVAS	0.55***	-	0.62***	0.56***
	(0.04)	-	(0.04)	(0.05)
R&D business function	-	-0.02	-0.02	-0.02
	-	(0.02)	(0.02)	(0.02)
Fabrication business function	-	0.01	0.00	-0.11*
	-	(0.02)	(0.01)	(0.04)
Marketing business function	-	-0.06**	-0.06***	-0.06***
	-	(0.02)	(0.02)	(0.02)
Fabrication business function	-	-	-	0.16*
x FVAS	-	-	-	(0.06)
Time effects	Yes	Yes	Yes	Yes
Country-industry effects	Yes	Yes	Yes	Yes
Observations	23,023	23,023	23,023	23,023
Adjusted R-squared	0.53	0.52	0.53	0.53

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

view is that fabrication-related GVC participation provides disproportionate benefits (Rungi & Del Prete 2018) and that R&D-related GVC links stimulate knowledge-transfer. Also, it could be a hint for less value added being associated with tasks such as assembling which precede distribution and marketing as shown by Stöllinger (2021). Indeed, this is often identified as a problem for countries successful at manufacturing, but lacking the distribution channels (e.g. suppliers of the German automotive industry).

Further, we would like to see how GVC participation interacts with the fabrication business function. Do fabricated-oriented industries profit from knowledge spillovers if they are exposed to trade partners engaged in R&D? Letting the now split FVAS interact with the fabrication business functions, it is apparent that it is indeed only the R&D-related GVC participation that makes fabrication competitive (column 2). A possible explanation is that the interaction with more advanced trade partners induces knowledge transfer and thus process upgrading. GVC participation with partners focused on other business functions does not interact with the relationship between value added and the fabrication business function in any discernible way (columns 2 and 3).

The interaction between fabrication and GVC participation may also rely on the grouping of the business functions. As a robustness check, we consider fabrication and headquarter activities (adding R&D, management, and marketing together) to see whether our results hold. Management dilutes the effect of the remaining business functions, but the main conclusions of this paper are robust to this exclusion. The results are presented in appendix A2.

3.4.2 Intra-industry GVCs and functional specialization

To test whether intra-industry GVC participation is more beneficial than the inter-industry kind, we calculate an FVAS measure that only captures GVC participation within the given industry. The results in column 1 of Table 3.6 suggest a strong positive association between intra-industry GVC participation and value-added. The association is stronger than the GVC participation of the inter-industry kind. Interactions with the fabrication business function (column 2) reveal that this difference is even more pronounced for industries not active in fabrication which is in line with our previous results. Surprisingly, this effect is not observed in the case of intra-industry GVC participation (column 3) suggesting that process upgrading in fabrication happens mainly across and not within industries which contradicts a view of gradual improvement by

Table 3.5: FVAS split by partnerâ€™s business function

	(1)	(2)	(3)	(4)
Capital	0.56***	0.56***	0.56***	0.56***
	(0.01)	(0.01)	(0.01)	(0.01)
Labor	0.26***	0.26***	0.26***	0.26***
	(0.01)	(0.01)	(0.01)	(0.01)
R&D business function	0.27***	0.25***	0.26***	0.27***
	(0.06)	(0.06)	(0.06)	(0.06)
Fabrication business function	0.28***	-0.85**	0.52***	0.25
	(0.05)	(0.30)	(0.15)	(0.18)
Marketing business function	0.19***	0.18**	0.18**	0.19**
	(0.06)	(0.06)	(0.06)	(0.06)
FVAS from R&D	0.91***	0.57**	0.86***	0.91***
	(0.18)	(0.20)	(0.18)	(0.18)
FVAS from Fabrication	1.06***	0.93***	1.23***	1.04***
	(0.10)	(0.11)	(0.16)	(0.11)
FVAS from Marketing	0.46***	0.50***	0.43**	0.45***
	(0.12)	(0.13)	(0.13)	(0.13)
Fabrication business function	-	1.15***	-	-
x FVAS from R&D	-	(0.30)	-	-
Fabrication business function	-	-	-0.26	-
x FVAS from Fabrication	-	-	(0.16)	-
Fabrication business function	-	-	-	0.04
x FVAS from Marketing	-	-	-	(0.18)
Time effects	Yes	Yes	Yes	Yes
Country-industry effects	Yes	Yes	Yes	Yes
Observations	23,023	23,023	23,023	23,023
Adjusted R-squared	0.53	0.52	0.53	0.53

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

implementing manufacturing standards and best practices within a specific sector. Such results are, however, preliminary because our distinction of intra- and inter-industry GVC participation relies on the granularity of the given data. If inter-industry GVC participation had stronger effects across more related industries, more granular data would yield different results.

Table 3.6: Intra-industry GVC participation

	(1)	(2)	(3)
Capital	0.56***	0.56***	0.56***
	(0.01)	(0.01)	(0.01)
Labor	0.25***	0.25***	0.25***
	(0.02)	(0.02)	(0.02)
R&D business function	0.04	0.04	0.04
	(0.06)	(0.6)	(0.06)
Fabrication business function	0.05	-0.5	0.05
	(0.06)	(0.07)	(0.06)
Marketing business function	0.00	-0.00	0.00
	(0.06)	(0.07)	(0.06)
FVAS-rest	0.80***	0.74***	0.80***
	(0.05)	(0.05)	(0.05)
FVAS-intra	1.95***	1.98***	1.99***
	(0.18)	(0.18)	(0.24)
FVAS-rest	-	0.14**	-
x Fabrication business function	-	(0.06)	-
FVAS-intra	-	-	-0.09
x Fabrication business function	-	-	(0.28)
Time effects	Yes	Yes	Yes
Country-industry effects	Yes	Yes	Yes
Observations	23,023	23,023	23,023
Adjusted R-squared	0.53	0.52	0.53

**** p<0.01, ** p<0.05, * p<0.1.*

3.4.3 Does country development matter?

Focusing only on the inter-industry GVC relations neglects another potentially important source of FVAS effects heterogeneity - country heterogeneity. Path dependency also plays a role as GVC participants from developed countries may enjoy greater value added due to their traditionally favorable position on the market. Following Kummritz (2015) we suspect these effects to be distinct in highly, more, and low-developed countries. We, therefore, make use of a nested model in which FVAS measures interact with a development group dummy.

The results in column 1 of Table 3.7 show that returns to the general GVC participation are the same across the board. These results are in line with those reported by Kummritz *et al.* (2017), who found that country development status did not influence GVC participation effects. However, if we distinguish between the business function of the GVC partner, country development matters as column 2 shows. The R&D-related GVC participation is linked to more value added for low-developed countries than for more and high-developed countries. It is perhaps no surprise that GVC participation with R&D-oriented partners gives the most benefit to the low-developed countries as those countries can profit from knowledge transfer. Contrarily, fabrication-related GVC participation is beneficial more for more and high-developed countries. This hints at the fact that outsourcing production to countries with cheap labor is profitable mainly for these two development groups - the receiving side of the outsourcing does not profit as much as the dominant players of the GVC.

3.5 Conclusion

In this paper we have analyzed the interplay between GVC participation and value added, illustrating the heterogeneity of GVC participation effects depending on stages of production which were proxied by functional specialization. There is a strong positive association between value added and GVC participation - this effect is even more important for fabrication-oriented industries. This likely stems from the closer links in a more rigid hierarchy present in manufacturing sectors (Gereffi *et al.* 2005) which induces technology gains (Ernst & Kim 2002) and results in process upgrading.

By distinguishing between FVAS related to R&D, fabrication, and marketing business function of the GVC partners, we have revealed the second dimension of heterogeneity in GVC participation effects. Because the structure of GVC participation changes across the production process, the aggregate effects may mask the true consequences of GVC hierarchy and technology gains. Deepening GVC participation with a partner focused on marketing provides significantly fewer benefits than R&D and fabrication-related GVC participation suggesting the unfavorable position of industries engaged in late fabrication stages, such as assembly. GVC hierarchy and severe competition in such tasks is the culprit of the uneven value added distribution (Gereffi *et al.* 2005).

Table 3.7: Using country development group dummy as an interaction term with FVAS

	(1)	(2)	(3)	(4)
Capital	0.57***	0.57**	* 0.57***	0.57***
	(0.01)	(0.01)	(0.01)	(0.01)
Labor	0.25***	0.25***	0.25***	0.25***
	(0.01)	(0.01)	(0.01)	(0.01)
R&D business function	0.04	0.29***	0.27***	0.27***
	(0.05)	(0.06)	(0.06)	(0.06)
Fabrication business function	0.05	0.28***	0.28***	0.28***
	(0.05)	(0.06)	(0.06)	(0.06)
Marketing business function	0.00	0.20**	0.19**	0.19**
	(0.06)	(0.06)	(0.06)	(0.06)
FVAS	0.64***	-	-	-
	(0.07)	-	-	-
FVAS x low-developed	0.02	-	-	-
	(0.09)	-	-	-
FVAS x high-developed	-0.05	-	-	-
	(0.08)	-	-	-
FVAS from R&D	-	0.86***	0.91***	0.91***
	-	(0.22)	(0.18)	(0.22)
FVAS from Fabrication	-	0.98***	1.23***	1.04***
	-	(0.10)	(0.14)	(0.11)
FVAS from Marketing	-	0.45***	0.46***	0.43**
	-	(0.13)	(0.12)	(0.16)
FVAS from R&D	-	0.91**	-	-
x low-developed	-	(0.31)	-	-
FVAS from Fabrication	-	-	-0.42*	-
x low-developed	-	-	(0.20)	-
FVAS from Marketing	-	-	-	0.11
x low-developed	-	-	-	(0.26)
FVAS from R&D	-	-0.04	-	-
x high-developed	-	(0.20)	-	-
FVAS from Fabrication	-	-	-0.14	-
x high-developed	-	-	(0.17)	-
FVAS from Marketing	-	-	-	0.03
x high-developed	-	-	-	(0.17)
Time effects	Yes	Yes	Yes	Yes
Country-industry effects	Yes	Yes	Yes	Yes
Observations	23,023	23,023	23,023	23,023
Adjusted R-squared	0.53	0.53	0.53	0.53

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Furthermore, countries could be particularly affected by GVC participation based on their development. By allotting the covered countries to groups of highly, more, and low-developed economies, we were able to show that whereas low-developed countries benefit from R&D-related GVC participation more than others, the opposite is true for fabrication-related GVC participation. Yet again, these findings support both the notion of technology transfer from countries with more competencies to those with fewer competencies. Fabrication-related GVC participation is less profitable for the low-developed countries likely because of their relatively weak competitive advantage of cheap labor in this particular business function. Generally, we did not find evidence supporting or the hypothesis of the global North benefiting more greatly from GVC participation than the global South.

Except for looking deeper into the functional upgrading of industries and countries, it is also worthwhile to investigate the heterogeneity of the GVC effects among income groups of individuals. Examining the association between wage distribution and GVC participation should be the next step in this line of research. Similarly, expanding the data sample to cover more developing economies is a crucial step to informed development policy. More can be also said about the drivers of the heterogeneity of GVC participation effects. As an example, R&D expenditures may stimulate technology gains from GVC participation through greater absorption capacity Mancusi (2008). Policy would then be able to focus on increasing the benefits of GVC participation as well as on mitigating the potential harm it causes.

Chapter 4

Heterogeneity of GVC Participation Effects and Its Catalysts

4.1 Introduction

A growing body of economic papers argues that although beneficial on aggregate, international trade creates winners and losers. The losers can be societies previously focused on an outsourced industry (Autor et al., 2016), firms in subservient global value chain (GVC) positions (Gereffi et al., 2005a), but also the whole economies which miss their growth potential through misguided policies (Baldwin, 2016a). We set out to show that GVC participation indeed spurs economic growth heterogeneously, i.e., the relative development of the participating economies influences the way these economies benefit from the participation and that its effects can be further influenced by policy, particularly by building a knowledge base in an industry via research and development (R&D) spending. We further strengthen this line of argumentation by showing that even the way foreign direct investment (FDI) links to value added depends on R&D.

Ever since Ricardo, international trade has been recognized as one of the drivers of economic development (Ricardo, 1891). Comparative advantage makes the developed economies specialize in capital and high-skill labor-intensive industries whereas the low-skill labor-intensive sectors were outsourced to the developing countries (Heckscher 1919). Winners and losers were easily identified in this model. Low-skill labor in the developed economies faces new competition whereas high-skill labor and capital raise their returns because of their relative scarcity. This model becomes less relevant with rising substitutability of the factors of production as the same products can often be produced by a variety of input factors mixes Sala & Trivín (2018). Factors of production thus compete with one another as the same product can be produced either by a process relying on manual labor and rudimentary devices or a process based on high-skill labor and sophisticated machines. The distinction between winners and losers of the international trade thus becomes increasingly obscured.

With ever-decreasing coordination and transportation costs, the competition shifted from final and intermediary products to tasks and competencies (Grossman & Rossi-Hansberg, 2008; Baldwin, 2016). The unbundled production organized itself into complex value chains which often span around the globe using various competency clusters (Bettiol et al., 2017). Value added of the production is unevenly distributed within the GVCs and reflects the GVC hierarchy which is in turn dependent on the competencies of the GVC participants (Gereffi *et al.* 2005). However, the empirical analysis of the GVC participation effects often neglects the competencies of firms or competency levels of sectors as they are difficult to estimate. Linking the technological competency approximated by R&D stock with GVC participation measures is the main contribution of this paper.

GVC hierarchy is not defined solely by technological competencies. Countries that managed to put their firms in the center of the production processes often benefit from their past success. They retain the technological prowess but the fact that they functionally specialize in headquarter tasks indicates strong path dependency (Stöllinger 2021). FDI stock, both outward and inward, suggests integration in the global economy with relatively strict hierarchical mode of governance. Indeed, the investments correspond closely to the GVC participation measures (Comotti et al., 2020). Outward FDI stock can thus serve as a complementary indicator to the R&D stock which focuses solely on the competencies.

We attempt to relate GVC participation with competencies by using the World Input-Output Database (WIOD) and combining it with R&D expenditures in 49 Czech industrial sectors over the 2000-2014 period. Using foreign value-added share as a proxy for GVC participation, R&D capital stock as a proxy for competency, and FDI stocks as complementary indicator reflecting GVC hierarchy creates an opportunity to inspect whether increasing competency or hierarchical standing indeed corresponds to more beneficial GVC participation. Evidence in support of this hypothesis can serve as an additional argument for spurring R&D spending and designing policies aiming to attract foreign investment.

The analysis of Czech sectoral data show that benefits of GVC participation are not uniform across the board. GVC participation benefits are mainly driven by links to partners with higher level of economic development. There are further stimulated by R&D stock of the respective sector. This is not the case for links to less-developed countries. The relationship of inward FDI stock and value added is positive but the that of outward stock is negative. This is, however, likely caused by the structure of the data. The paper is structured in the following way: section 2 introduces the theory, explains the key concepts, and review papers relevant to the study. Section 3 presents the data and methods. section 4 discusses the empirical results, and section 5 concludes the paper.

4.2 Theory, concepts, hypotheses

The issue of economic development is the cornerstone of economic thought. Long-term economic growth is strongly linked to inclusive institutions (Acemoglu & Robinson 2012). The short-term growth has become recently more dependent on the way the countries manage to link themselves to the global economy (Baldwin, 2016). With new insights about the hierarchy reigning in the GVCs (Frederick, 2014), the distribution of value added in the world economy and its driving factors has become relevant for developing countries, and also for developed countries that try to catch up with their still more advanced peers. It thus no longer suffices to ask what factors drive economic growth. The question of which factors only influence the value distribution in the world economy, and which also spur economic development has become pressing.

One of the prime suspects of a factor influencing value-added distribution as well as long-term economic development is R&D investment. Griliches (1979) introduced a framework for estimating R&D returns, and since then, research has relatively consistently presented evidence of R&D stock being related to greater value added (Hall *et al.* 2010). This is not the case only for direct returns, i.e., the effects on the investing firm or industry, but also on the surrounding economy through spillovers. Indeed, the spillovers are present, and although they do not remain constant over time (Lucking *et al.* 2018), they stay relevant and both statistically and economically significant (Lucking et al., 2020).

The most recent meta-analysis by Ugur et al. (2020) confirms that the direct R&D returns are positive along with positive and statistically significant spillovers. However, there is a strong indication of heterogeneity of the spillovers as they are significant only for the subset of the OECD countries. The authors attribute the heterogeneity to the absorptive capacity - the existing R&D stock helps the firms benefit from R&D spending different from their own. The logic of absorptive capacity can, however, be used also for technology transfer via GVC participation. GVC participation could work hand in hand with R&D spending in the quest of economic development.

Hypothesis 5. The benefits of GVC participation are stimulated by R&D stock.

Effects of GVC participation can be heterogenous not just because of the characteristics of the respective country - such as absorptive capacity. GVC participation itself can vary in terms of power relations within the GVCs (Frederick, 2014). Distinguishing between the source countries of the GVC participation, it is possible to investigate how R&D stock stimulates either GVC participation with developed or developing countries. Given the thesis of uneven power relations defining value added distribution (Kaplinsky, 2000), the effect of absorptive capacity should be mostly pronounced in interaction with GVC participation with developed countries.

Hypothesis 6. R&D stock stimulates the benefits of GVC participation with developed countries.

Another factor codetermining the value-added distribution is FDI, one of the modes of integration into the global economy. Whereas countries with sufficient size and resources can shield their industries from foreign competition and build the domestic technological capacity, smaller economies rather pursue the strategy of attracting FDI with the hope of technology spilling over to their domestic firms (Gereffi, 2009). Such strategy works. (Demena & van Bergeijk 2017) provide a meta-analysis of FDI spillovers showing, that despite publication bias, the spillovers are positive and statistically significant.

FDI is also instrumental in GVC architecture. As Amador & Cabral (2016) note, multinational enterprises (MNE) use FDI to set up a new chain. Such a GVC is highly hierarchical with the dominant MNE positioned in its center. Part of inward FDI thus can be assigned to deepening GVC participation, particularly in the position of a junior partner. But even a strictly hierarchical GVC can provide benefits in terms of technology spillovers. The question is whether R&D stock provides absorptive capacity to industries with significant inward FDI stock and thus stimulate the spillovers.

Hypothesis 7. The FDI spillovers are stimulated by R&D stock.

GVC participation can indeed happen through FDI which suggests a strong hierarchical organization. Is such a setting beneficial for the receiving country? Or is it the investing country that profits? Or does it depend on whether the GVC participation happens with developing or developed countries? We hypothesize that tight and hierarchical relationship provides a breeding ground for technology spillovers. It might be that in the long term, such a GVC architecture hinder the development of the less developed partners, but it nonetheless stimulates the technology transfer at the given moment.

Hypothesis 8. The FVAS benefits are stimulated by inward FDI.

4.3 Data and methodology

Although our analysis concerns Czech sectors, we are interested in all their international links. We thus use the World Input-Output Database â€“ release 2016 provides a panel of 53 industries in 43 countries over the period 2000-2014 â€“ using just the data for Czech sectors (Timmer *et al.* 2015). WIOD also provides socio-economic accounts for value added, capital, and labor employed which we use in our model. All currency-based variables (i.e., all variables except for labor which is calculated full-time equivalents) are converted to US dollars and use 2010 prices. To get a proxy for GVC participation, we calculate foreign value added share measures (FVAS) following Los *et al.* (2015). FVAS, measure of international integration, tells us how much of the total value added of the particular GVC is produced abroad.

$$FVAS_{CZE}(j) = \frac{\sum_{c,k:c\neq CZE} VA(j)(c,k)}{\sum_{k} VA(j)(c,k)} \tag{4.1}$$

where $VA(j)(c,k)$ describes value added of a Czech industry j produced in industry k of country c, its GVC partner. The value added created in each industry is given by the vector $\mathbf{g}$:

$$\mathbf{g} = \hat{\mathbf{v}}(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}(\mathbf{Fe}) \tag{4.2}$$

In this equation, $\hat{\mathbf{v}}$ is a matrix with value added over gross output on its diagonal, $(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}$ is the standard Leontief inverse, $\mathbf{F}$ is the matrix of the final output, and $\mathbf{e}$ is the summation vector.

FVAS is easy to slice. We can then discern FVAS coming from a set of different countries, differentiating the effects of GVC integration with the old EU member states, with the new EU member states, with other OECD countries, and with the rest of the world. The equation below shows the calculation of FVAS from other OECD countries (where we disregard Czech Republic and EU countries which are also OECD members). The other country groups are calculated accordingly:

$$FVAS - OECD(j) = \frac{\sum_{c,k:c \in OECD} VA(j)(c,k)}{\sum_{k} VA(j)(c,k)} \tag{4.3}$$

Having the information about sectoral GVC participation, we want to combine it with R&D data to investigate the interplay between R&D capacity and GVC participation effects. Eurostat provides sectoral data on R&D expenditure for Czechia in years 2005-2018. After readjusting for different sectoral granularity of the datasets and putting the R&D expenditures into 2010 prices in USD, we calculate R&D capital stocks. This is to reflect the lagged effect of R&D expenditure on the value added. We follow Hall et al. (2010) in the calculations.

$$R_t = (1 - \delta)R_{t-1} + r_t \tag{4.4}$$

The iterative approach requires R&D capital stock at time 1. Assuming constant growth rate of the R&D expenditures and a constant depreciation rate (Hall *et al.* 2010), we arrive at:

$$R_2 = \frac{r_1}{g + \delta} \tag{4.5}$$

Hence, we lose the first observation and arrive at a dataset spanning from 2006 to 2015 for 49 sectors.[1]

In the second part of the empirical analysis, we use FDI stock data as they are reported by the Czech National Bank. Their sectoral classification

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[1] As in Pleticha (2021), we omitted the sector.*manufacture of coke and refined petroleum products* because of the highly unstable price index.

is different from WIOD, so we are forced to drop a portion of sectors and use only those where the two classifications overlap. This naturally introduces issues of limited dataset and the potential bias of the results as the missing values are likely not distributed at random. Indeed, they are not, as majority of the missing values are in the services sectors. Thus, the results with FDI data should be interpreted with caution and realization, that the underlying data represent disproportionately the manufacturing sectors.

Table 4.1: Summary Statistics

	N	MEAN	SD	MIN	MAX
Capital stock (CZK millions)	470	15,666	38,422	0	340,430
Labor (FTE)	470	151	144	1	584
Value Added (CZK millions)	470	3,152	3,268	4	19,116
R&D Stock (CZK millions)	424	166	243	0	2,137
FVAS total	470	0.24	0.12	0	0.56
o/w FVAS from high-developed	424	0.05	0.05	0	0.21
FVAS from less developed	424	0.19	0.08	0	0.38
Inward FDI Stock (CZK millions)	243	45,205	76,968	-44	661,362
Outward FDI Stock (CZK millions)	243	5,239	22,148	-1,487	233,504

Source: Author's computations

The empirical strategy follows Kummritz *et al.* (2017). We estimate the model based on a standard production function.

$$Y(A,F) = F_1(FVAS, ...)F_2(K,L) = AL^{\beta_1}C^{\beta_2}K^{\beta_3}FVAS^{\beta_4}e^{u} \tag{4.6}$$

where A is the shared technology for all industries, L and C are the labor and capital inputs respectively, K is the R&D intensity and FVAS is the measure for GVC participation, and u is the error term. $\beta_1, \beta_2, \beta_3, \beta_4$ are the respective elasticity coefficients. Taking a logarithmic transformation and controlling for a common technology development, we get:

$$y_{jt} = a_j + \beta_1 l_{jt} + \beta_2 c_{jt} + \beta_3 k_{jt} + \beta_4 FVAS_{jt} + \lambda_t + u_{jt} \tag{4.7}$$

The model specification suffers from the obvious issue of endogeneity. It is therefore an exploratory analysis which merely suggest potential causal links between GVC participation, R&D, FDI, and value added.

results to previous research. The estimates of labor and capital shares fall in line with studies which used similar data - so are the returns to R&D (Hall *et al.* 2010; Sveikauskas 2007; Ortega-Argilés *et al.* 2010). GVC participation is related to greater sectoral value added which also mostly confirms the finding of other scholars (Kummritz *et al.* 2017; Kordalska *et al.* 2016). Splitting GVC participation into that linked to the high- and less-developed countries (see the appendix for the country groups) reveals that Czech industries benefit markedly by GVC participation with the high-developed sort.

This cannot be bluntly interpreted as evidence for technology transfer though. GVC participation with high-developed countries serves also as an opportunity for functional upgrading - integrating and potentially moving up in the GVC hierarchy. However, such a distinction shows that GVC participation with less-developed countries does not benefit the Czech industries at all and thus the premise of value chain dominated by the Czech firms where the Czech firms reap disproportionate value added is likely false. This is in strong contradiction with economic strategies which aim and diversification of foreign trade links - specifically towards the less developed countries which are considered as a unique trade opportunity (Hesse *et al.* 2009). However, this could be also caused by non-linear relationship between productivity and export diversification as (Xuefeng & Yaşar 2016) show.

To see whether R&D capacity interacts with the GVC participation, we investigate the specification of models 3, 4, and 5. Whereas the general measure of GVC participation remains the same when interacted with R&D stock (model 3), splitting the GVC participation once again provides a more elaborate picture. It is only the GVC participation with high-developed partners which is stimulated by greater R&D stock. These results suggest that, in the context of Czech industries, R&D stock serves rather as an absorptive capacity proxy (Griffith *et al.* 2004). The notion of using the technological capability to benefit from links with less developed partners remains, as in the previous case, unfounded.

Foreign value-added share is only one way how to look at the GVC participation. A measure reflecting a rather stricter GVC integration is FDI. FDI and FVAS measure (and even R&D stock) clearly describe the same complex phenomenon which is reflected in the instability of the coefficient estimates once inward and outward FDI stocks are added into the model.[2] Including the FDI stocks renders FVAS insignificant. But it also shows the inward FDI is

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[2] The instability is partially caused also by the limited dataset. That is the case mostly

Table 4.2: GVC participation and R&D stock; interactions

	(1)	(2)	(3)	(4)	(5)
Capital	0.35***	0.36***	0.36***	0.36***	0.36***
	(0.05)	(0.05)	(0.03)	(0.03)	(0.03)
Labor	0.68***	0.67***	0.67***	0.67***	0.67***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
R&D Stock	0.08**	-	0.01	0.06	0.53*
	(0.03)	-	(0.04)	(0.04)	(0.30)
FVAS	2.21*	-	-2.14	-	-
	(0.98)	-	(3.04)	-	-
FVAS from high-developed	-	7.44*	-	-12.60	7.17
countries	-	(3.14)	-	(9.74)	(3.29)
FVAS from high-developed	-	-	-	1.63*	-
countries x R&D Stock	-	-	-	(0.74)	-
FVAS from less-developed	-	-3.84	-	-4.44	-10.59
countries	-	(3.42)	-	(3.44)	(5.71)
FVAS from less-developed	-	-	-	-	0.50
countries x R&D Stock	-	-	-	-	(0.41
Time effects	Yes	Yes	Yes	Yes	Yes
Country-industry effects	Yes	Yes	Yes	Yes	Yes
Observations	415	415	415	415	415
Adjusted R-squared	0.86	0.87	0.87	0.87	0.87

*** p<0.01, ** p<0.05, * p<0.1.

remarkably beneficial for greater value added. This is not the case with the outward FDI stock which is related to less value added.

Whereas the inward FDI stock has been repeatedly related to greater productivity and thus greater value added (Demena & van Bergeijk 2017), the outward FDI stock's negative sign is not well-established in the literature (Herzer 2010; Lee 2010). The reason for that might be the fact that outward FDI at industry level means outsourcing of the tasks which are the essence of that very industry. If, for instance, an automotive firm engages in outward FDI, it is likely that it outsources mainly the assembling parts of the production chains. The services, which are likely to fall into different categories of our sector classification remain in-house. This means that even if the outward FDI benefits the firm and the economy, it, at the sectoral level, relates to value added negatively.

Table 4.3: GVC participation, R&D stock and FDI; interactions

	(1)	(2)	(3)
Capital	0.35***	0.36***	0.36***
	(0.03)	(0.04)	(0.04)
Labor	0.65***	0.65***	0.65***
	(0.04)	(0.04)	(0.04)
R&D Stock	0.32*	0.35	0.40
	(0.11)	(0.23)	(0.23)
FVAS	-0.25	-0.20	-0.24
	(0.82)	(0.52)	(0.83)
Inward FDI stock	0.16***	0.15***	0.11
	(0.04)	(0.04)	(0.06)
Outward FDI stock	-0.06*	-0.12**	-0.06**
	(0.03)	(0.04)	(0.03)
Inward FDI stock x R&D stock	-	-	0.00
	-	-	(0.01)
Outward FDI stock x R&D stock	-	0.01*	-
	-	(0.00)	-
Time effects	Yes	Yes	Yes
Country-industry effects	Yes	Yes	Yes
Observations	234	234	234
Adjusted R-squared	0.88	0.88	0.88

**** $p<0.01$, ** $p<0.05$, * $p<0.1$.*

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with the R&D returns. They seem to be inflated by the fact that the dataset reflects only those industries which in FDI database provided the Czech National Bank.

Such a narrative corresponds with the findings of the second model (column 2). A more R&D intensive sectors lose less from outward FDI.[3] Indeed, being more technologically advanced to begin with possibly means that there are fewer menial tasks to be outsourced. The negative relationship is then still present but diminished. In either case, it is likely an attribute of the granularity of our data, not a result easily transferable to other economic subjects, such as firms. Finally, the interaction of inward FDI stock and R&D stock is statistically irrelevant. This is an indication that in the more hierarchical organization of the value chain, the absorptive capacity is less relevant than in the looser organization. Such a result is also in line with intuition behind qualitative analysis provided by Kaplinsky & Morris (2000). Indeed, the value chains organized in a looser fashion provides greater opportunity to functionally upgrade - and that is achieved by building up absorptive capacity including R&D stock.

4.4 Conclusion

In this paper we have analyzed the heterogeneous effects of R&D, FDI investment, and GVC participation using Czech sectoral data. We have shown that it is mainly GVC participation with high-developed countries that is linked with higher value added. Such a positive relationship is further enhanced by higher R&D stock. Using a related measure for foreign trade integration, FDI, revealed positive relationship with value added in the case of inward FDI and negative in case of outward FDI. The negative relationship of outward FDI and value added is mitigated by R&D spending. The counterintuitive results of outward FDI can be attributed to the characteristics of the data.

Our analysis has naturally its limits. The model specification does not allow for causal interpretation and thus, the results should be interpreted only in an exploratory fashion. Moreover, the FDI data are far from complete which makes the results of the regression including FDI biased towards the true relationship present solely in manufacturing. Firm-level data would enable us to circumvent such issues and even deal with endogeneity but a comprehensive dataset including information about firms' suppliers and customers is, to the author's knowledge, currently not available.

The results suggest that R&D stock is a good proxy for the capability of

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[3] The interaction can also be interpreted such that outward FDI increases the R&D returns. The interaction term cuts both ways.

catching up with more advanced economies but, at least for post-transition countries such as the Czech Republic, it does not serve as a sufficient condition for the ability to build a value chain around the domestic industry and use its centrality for its own benefit in terms of value-added distribution. In other words, Czech industrial capabilities reflected in the R&D stock have so far not reached the level with sufficient gravity to functionally upgrade in substantial way within the existing value chains or organize brand new value chains around those newly acquired capabilities. Such results could either hint to the fact that capabilities are not a deciding factor in the GVC organization or that countries such as Czechia have not yet reached the critical mass of their industrial knowledge.

To decide which one of these hypotheses is true is beyond the scope of this paper. However, future research should address such problems due to their policy relevance. Although R&D research is surely beneficial by its own right, its utility as a tool for succeeding on the global markets is far less clear. Yet the right policy mix of public and private R&D spending, attracting foreign investment and participating in global value chains is likely is necessary both for advanced countries such as Czechia aiming to catch up with their western neighbors as well as developing countries avoiding the middle income trap.

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