



# Shift in the Importance of Consumption of Professional Services and Investments (GFCF) for Manufacturing Industries by R&D Intensity in Advanced Economies

 Anastasiia Alekhnovich <sup>(a)</sup>,  Leonid Anuchin <sup>(b)\*</sup>



<sup>(a)</sup> Faculty of International Management and Business, Budapest Business University, Budapest, Hungary.

<sup>(b)</sup> Faculty of Economic and Social Sciences, Budapest University of Technology and Economics, Budapest, Hungary.

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## ABSTRACT

The research revealed and analysed a trend, between 1995-2020, of a declining gross fixed capital formation (GFCF) to domestic value added in gross exports (DVA in Gross exports) ratio in manufacturing industries for most Advanced Economies, which occurred on the backdrop of increasing of intermediate consumption of professional services. Our model proves the partial substitution of GFCF with intermediate consumption of professional services in Advanced Economies due to the change of production operating model (value chain management in manufacturing industries), which is evidenced by high influence of the combined factor on the DVA in Gross exports. This substitution facilitates the upgrading of value chain by creation of backward and forward linkages for manufacturing industries, depending on their R&D intensity. Systemic and long-term nature of changes may reflect potential paradigm shift in Advanced Economies' production operating models.

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## Introduction

This research examines how investments (gross fixed capital formation, or GFCF) and intermediate consumption of professional services of manufacturing industries affect domestic value added in exports of manufacturing industries (DVA in Gross exports). This study investigates how these two factors influence trade patterns, considering the country's level of economic development, the differences in R&D intensity within industries and the distinct characteristics of the last two periods of world trade (1995-2007 and 2010-2020).

DVA in Gross exports estimates the value added an economy generates in producing goods and services for export (OECD, 2024d). It reflects the exported value added that has been generated anywhere in the domestic economy (not only by the exporting industry). Manufacturing industries with higher DVA in Gross exports to total value added of the industry act as a catalyst for other national industries by boosting domestic demand for intermediate goods and services. Moreover world-competitive technologies of exporting industries improve the technological capabilities of other industries across the whole value chain. It also proves genuine global competitiveness of that industry's manufactured products (Koopman et al., 2012, 2014).

This aligns with the principles of the Ricardian model of comparative advantage. Deb and Hauk (2017) propose an updated approach to assess national competitiveness (based on the Ricardian model) using Revealed Comparative Advantage (RCA) indices. Their approach focuses on DVA in Gross exports, rather than the total Gross exports, providing a more accurate picture of a country's true competitiveness in international trade.

Considering the ongoing servitization of manufacturing, alongside advancements in technology and automation (Baines et al., 2017), this study also assessed how combined GFCF and intermediate consumption of professional services jointly influence DVA in Gross exports across manufacturing industries. Both factors (GFCF and intermediate consumption of professional services) are crucial for industrial upgrading (Greffeti & Stark, 2016). Successful upgrading, as outlined by the Smile Curve theory, allows manufacturing industries to reach higher value added positions in the global value chains through creation of backward and forward linkages for manufacturing industries (Baldwin&Ito, 2022, Gáspár et al., 2023).

Our research utilised data on Trade in value added from the 2023 edition (TiVa, OECD, 2023e) and OECD Inter-Country Input-Output Database (ICIO) covering the period from 1995 to 2020 for 16 manufacturing industries and industry groups (Section C) across 76 countries (OECD, 2023a).

For research we elaborated the model of assessing linkages between two factors (GFCF, intermediate consumption of professional services across manufacturing industries) and DVA in Gross exports of manufacturing industries (Packages: Statsmodels 0.14.1 for Python and Statgraphics 18).

## **Literature Review**

It is recognized in the scientific community, business and politics sphere that participation in Global Value Chains (GVCs) contributes to economic development. However, researchers caution that not all countries can achieve this success equally (Kummritz, 2016). One of the main indicators proving success is how much value added a country adds domestically to its exports (Koopman et al., 2012, Koopman et al., 2014, Carballo & Jiang, 2016).

We would like to emphasize, that solely increasing domestic value added within commodity sectors offers limited potential to significantly boost a country's GDP growth. This is caused by the fact that mining and export of commodities already represent maximum domestic value added in Gross exports (DVA in Gross exports), as the extracted raw materials themselves constitute the internal value added. Moreover, income from these activities can be significantly influenced by commodity market prices (Johnson & Noguera, 2012). In this regard, the most promising avenues for boosting growth of DVA in Gross exports lie in the modern industrial sectors, with significant intermediate consumption of professional services (i.e., Stehrer et al., 2015, Nayyar et al., 2023, Rodrik et al., 2024).

Modern economic theory associates increasing domestic value added in exporting industries with the concept of upgrading. There are several types of industrial upgrading, implemented at both the macro level (across entire industries) and the micro level (within individual companies). These types can be categorized into four main areas: product upgrading, process upgrading, functional upgrading, and chain or inter-sectoral upgrading (Humphrey & Schmitz, 2002). Additionally, other important aspects of upgrading include entry into global value chains, strengthening backward linkages with domestic suppliers, and achieving end-market upgrading (Gereffi & Fernandez-Stark, 2016). Successful upgrading, as outlined by the Smile Curve theory, allows manufacturing industries to reach higher value added positions in the GVCs (Baldwin & Ito, 2022).

The scientific literature identifies various factors influencing industrial upgrading and DVA in Gross exports. For example, in one of the most fundamental research by Kummritz et al. (2017) examine the impact of infrastructure, connectivity, investment and trade policy, business climate and institutions, education and skills, product standards and innovation, labor standards, social standards, environmental standards for economic upgrading through GVC participation.

Several outstanding studies also investigate the role of professional services in growth of value added. The study of The Vienna Institute for International Economic Studies for the Directorate-General for Enterprise and Industry (Stehrer et al., 2015) analyses how the use of professional services by manufacturing industries in the EU impacts productivity growth in terms of value-added between 1995 and 2007. The researchers found that for EU-27 countries, services contribute roughly 40% of the value added in final manufactured products. This discovery highlights the growing importance of "servitization" trend within manufacturing. Experts categorized the professional services into three groups: upstream (development) services like R&D and design, core (production) services such as supply management and engineering, and downstream (market) services.

The study also revealed that larger countries benefit primarily from sourcing professional services from domestic suppliers, while smaller economies see greater value in sourcing professional services from international suppliers. This is particularly relevant for developing economies lacking sufficient domestic R&D funding and other intangible assets. The study also highlights that intermediate consumption services in manufacturing helps to increase competitiveness of manufacturers through outsourcing consumed services.

Therefore, consuming professional services directly supports upgrading and increasing value added and DVA in Gross exports of manufacturing industries, including producing both traditional and new industrial products based on product-service system in accordance with the concept of servitization of manufacturing (Baines et al., 2017).

Investments also play an important role in boosting DVA in Gross exports; however, the majority of articles primarily focus on foreign direct investment (FDI) as the main source of investment (i.e. Kummritz et al., 2017, Qiang et al., 2021, Anderson et al., 2019). This leaves a gap in estimation of contribution of domestically generated investments sourced by savings into upgrading projects and increasing DVA in Gross exports in manufacturing.

At the same time, the TiVa 2023 edition includes an indicator called gross fixed capital formation (GFCF) as element of final consumption by industries. This indicator reflects both domestic savings and foreign direct investment (FDI), but only when the FDI and savings contributes through financial channel to the creation of tangible or intangible assets (Eurostat, 2013).

It is notable, that regular reports of the European Investment Bank (EIB) investigate the relationship between GFCF and economic growth in terms of value added. Also the reports analyse the dynamics of special indicator - “productive investment” defined as total GFCF or net capital stock excluding dwellings (N111) but including other buildings and structures used for production (N112, e.g., factories, offices) (European Investment Bank, 2024).

There are also a number of articles on methods for calculating DVA in Gross export of manufacturing industries. Leading researchers noted that for quantifying the domestic value added generated by national economy participating in a GVCs it is necessary to access the flow dynamics of intermediate goods and services across borders. Baldwin and Lopez-Gonzalez (2015) posit three fundamental supply-chain trade concepts that influence DVA in Gross exports: importing for production, importing for export, and value-added trade. TiVa is a source that allows us to accumulate data on domestic value added based on these three elements and excludes double accounting (Koopman et al., 2014, Guilhoto et al., 2022).

The TiVa data source serves as a valuable resource for both academic research and practical applications. This is evidenced by its utilization by leading think tanks in the development of trade and economic policies (Chute et al. 2023 and etc). As for the base of the periodisation of international trade there are many diverse approaches highlighting different aspects or trends. In this research we used the division of periods based on accessing pace of share of global export and impot to global GDP, presented in the International Monetary Fund articles (Stanley, 2023, and etc.).

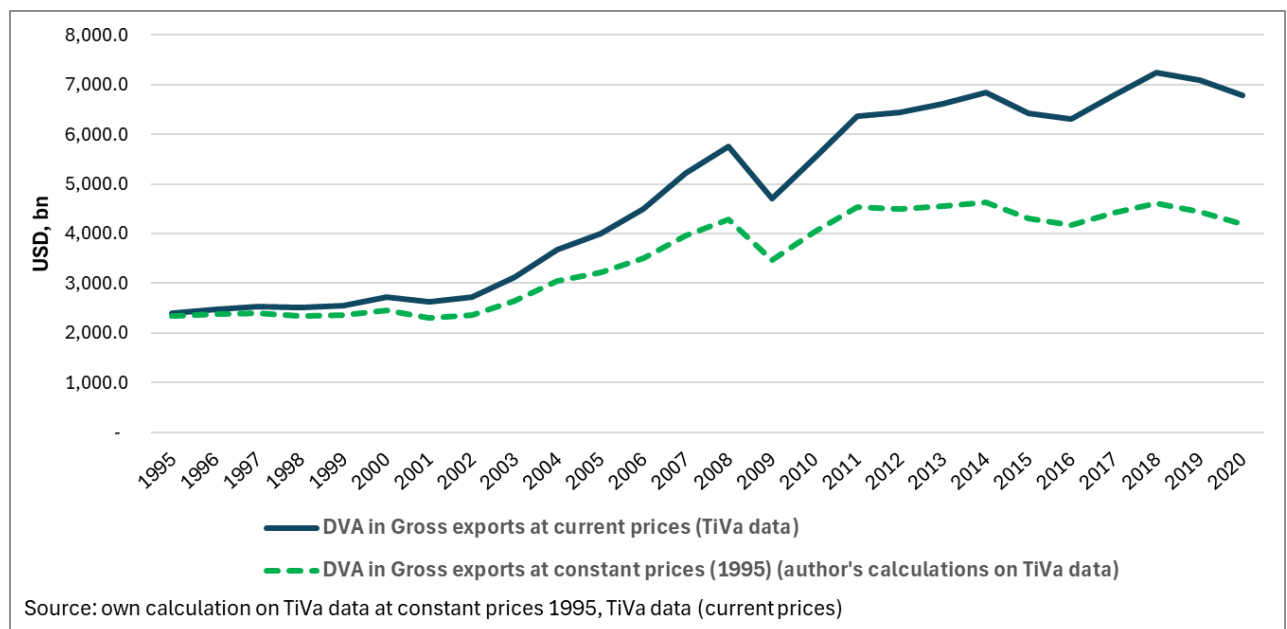
## Research and methodology

### Key trends of DVA in Gross exports of manufacturing industries in international trade

According to TiVa, global DVA in Gross exports in international trade (manufacturing industries – “C” section, excluding “C19” division) in current prices grew from USD 2.3 trillion in 1995 to USD 6.8 trillion in 2020.

At constant prices the indicator did not increase so significantly, by only (+78.7%) from USD 2.3 trillion to USD 4.2 trillion at constant prices (1995) between 1995 and 2020<sup>1</sup>.

Both for the largest economies and the entire sample of countries, DVA in Gross exports of manufacturing industries exhibited an upward trend at the first period from 1995 till 2007 (increasing by USD 1.62 trillion, +69.1%). However, the second period 2010-2020 saw a slowdown in DVA in Gross exports growth with increased volatility (total increase of USD 159 billion, +4.0%).



**Figure 1:** Global (World) DVA in Gross exports for manufacturing industries (“C” section excluding “C19” division) for 1995-2020, in current and constant USD.

<sup>1</sup> From this point forward, all prices are reported in USD at constant prices (1995)

DVA in Gross exports of manufacturing industries of the USA remained almost unchanged across the two periods, reaching USD 342 billion at constant prices (1995), representing a marginal increase of (+0.74%). G7 countries excluding the United States exhibited volatility: by the end of 2020, DVA in Gross exports in manufacturing industries in these countries decreased from USD 1,047 billion to USD 1,012 billion (-3.3%). Meanwhile, DVA in Gross export in other Advanced Economies (excluding all G7 members) grew from USD 586.7 billion to USD 971.6 billion (+65.6%).

Regarding Emerging Markets and Developing Economies across the two periods, China's DVA in Gross exports of manufacturing industries exhibited a significant increase, rising from USD 68 billion to USD 1,042 billion (+1,424%). Other economies in the group excluding China grew from USD 302 billion to USD 821 billion (+172%).

The trends reveal peculiar difference in DVA in Gross exports pace for Advanced Economies compared to Emerging Markets and Developing Economies between 2010 and 2020: all G7 countries and many other Advanced Economies revealed a pronounced decline in DVA in Gross exports for manufacturing industries. This observation may be partly attributed to the stricter quarantine measures implemented in Advanced Economies in 2020. However, a separate analysis of data from 2010 to 2019 compared to 2010 to 2020 revealed that the year 2020 did not exert a systemic influence on the overall declining trend.

To analyse qualitative changes in trends, a matrix analysis was conducted to examine the relationship between GFCF and intermediate consumption of professional services by manufacturing industries (section "C") and DVA in Gross exports of manufacturing industries. This analysis compares the beginning and the end years of two periods: 1995 to 2007 and 2010 to 2020 respectively.

The matrices indicated an interesting trend: while DVA in Gross exports in manufacturing industries increased across most observed countries during the first period (1995-2007), GFCF also generally rose. This effect was strongest in Emerging Markets and Developing Economies, potentially due to a low starting point (base effect), the relocation of production facilities from Advanced Economies, and activation of participation in GVCs. However, there are some outliers: several Emerging Markets and Developing Economies (Nigeria, Thailand, Peru, Malaysia) and even two advanced (Japan and Taiwan) saw DVA in Gross exports growth alongside a decrease in GFCF.

The analysis also demonstrated a positive relationship between DVA in Gross exports and intermediate consumption of professional services by manufacturing industries in most countries for 1995-2007. This effect was again most pronounced in Emerging Markets and Developing Economies, however, some outliers were present here as well: Argentina, the Philippines, and Portugal experienced growth in DVA in Gross exports growth despite a decrease in the consumption of professional services.

The observed positive trends in DVA in Gross exports, GFCF, and professional service consumption were not without interruptions. The analysis identified periods characterized by multidirectional change in all three indicators. These downturns coincided with two global crises: the Asian financial crisis of 1997-1998 and the dot-com bubble burst of 2001. The impact of these crises cascaded through various industries and their interconnected production networks, thus highlighting the inherent vulnerability of international trade and investments to exogenous shocks.

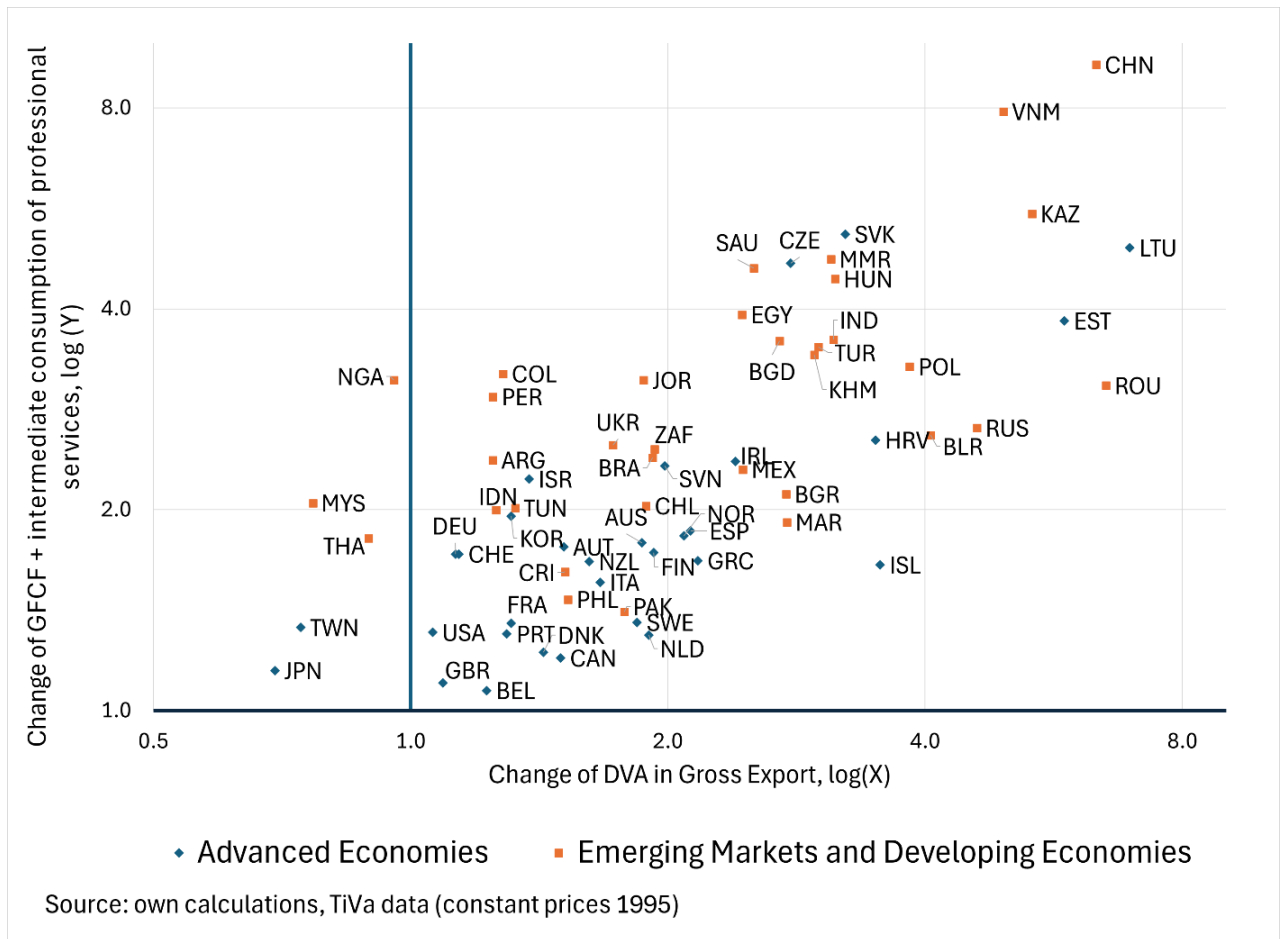
In the second period (since 2010 to 2020), matrix analysis revealed significant differences in the dynamics of both factors in relation to DVA in Gross export. Most economies still demonstrated strong co-directional change of DVA in Gross exports with GFCF and intermediate consumption of professional services by manufacturing industries (decrease in factor is mirrored by corresponding decrease in DVA in Gross exports, increase in factor - increase in DVA in Gross exports). However, a notable divergence emerged between Advanced Economies, Emerging Markets and Developing Economies. Advanced Economies generally exhibited a decline in both annual DVA in Gross exports and GFCF compared to 2010 levels. Conversely, Emerging Markets and Developing Economies continued to experience growth in both DVA in Gross exports and GFCF, further solidifying the trends observed during the first period.

Concomitantly, the analysis identified the emergence of two new distinct clusters of countries: one characterized by DVA in Gross exports growth alongside a decrease in GFCF, and the other exhibiting a decline in DVA in Gross exports despite an increase in GFCF.

As for intermediate consumption of professional services, a positive correlation with a larger number of countries was maintained. This is probably due to the expansion of servitization of manufacturing, when the consumption of services is integrated into the industrial value chain. Only in some countries, for different reasons, this causal relationship was broken (Cluster I: increase in DVA in Gross exports - decrease in consumption of professional services: Myanmar, Mexico, Turkey, Bulgaria, Israel, Taiwan; Cluster II: decrease in DVA in Gross exports - increase in consumption of professional services: Japan, Great Britain, Sweden, Pakistan, Malaysia, Peru).

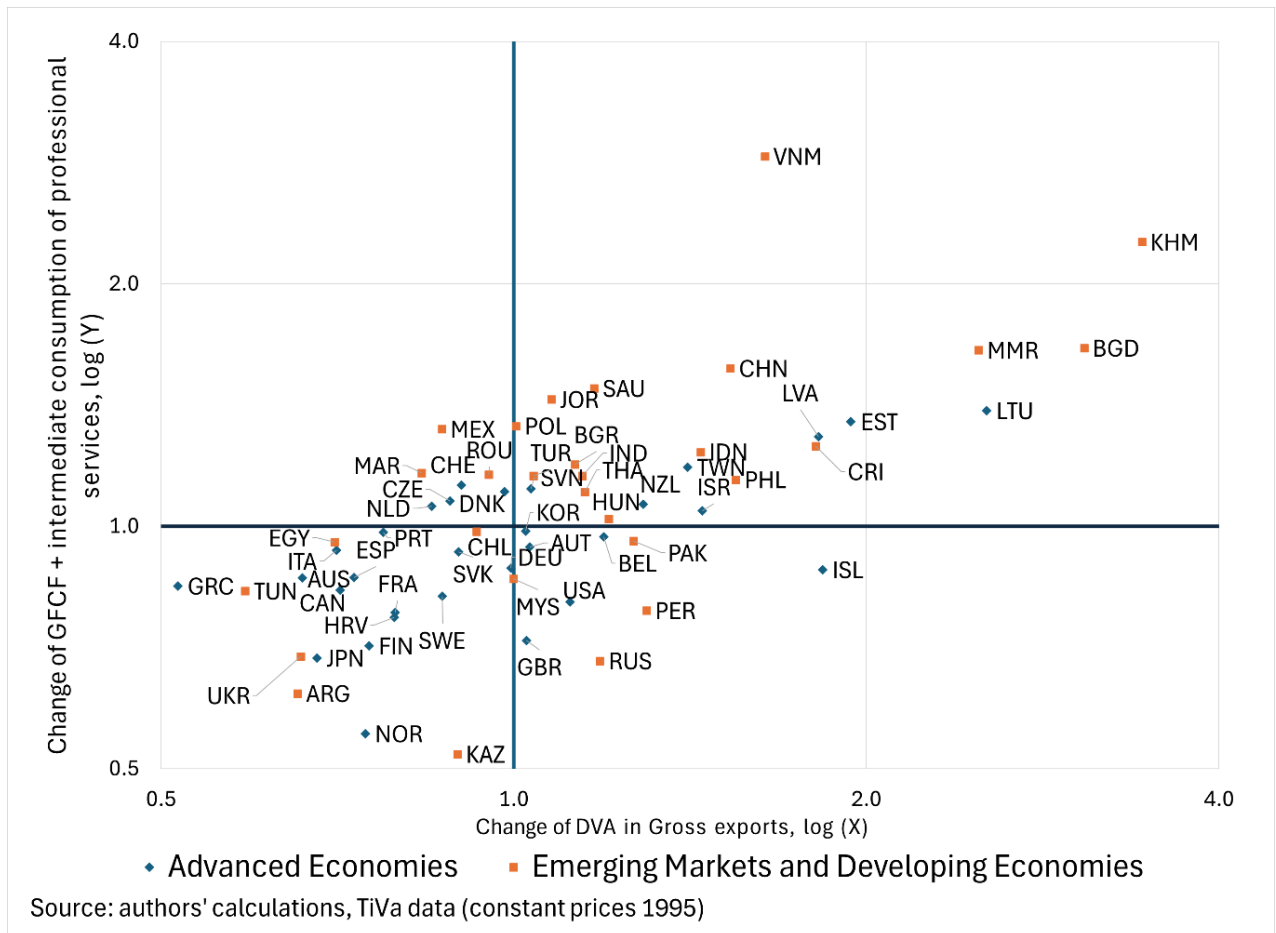
Since one of the goals of our study is to analyse the joint influence of two factors (GFCF and intermediate consumption of professional services) on DVA in Gross exports for two periods, matrix analysis was also carried out for the combined factor.

In the first period (1995-2007), for most of the countries studied, the combined influence of GFCF and intermediate consumption of professional services was co-directed with the dynamics of DVA in Gross exports. The outliers of the first period (Japan, Taiwan, Nigeria, Myanmar and Thailand) are much closer to the trend, than in the matrices assessing the influence of GFCF and intermediate consumption of professional services separately.



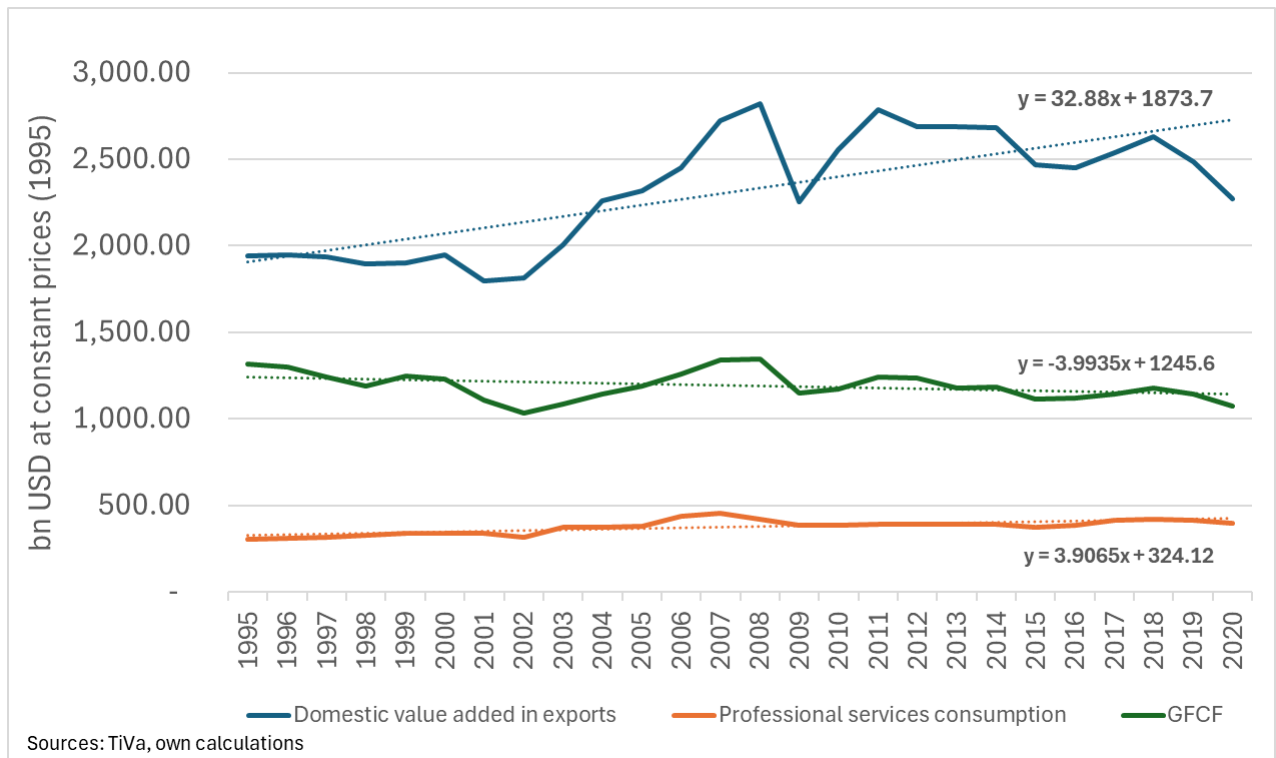
**Figure 2:** Change of DVA in Gross exports for manufacturing industries (log index change, x, 2007 to 1995) to combined change of GFCF and intermediate consumption of professional services (log index change, y, 2007 to 1995), MDAC

In the second period (2010-2020), the introduction of a combined factor also showed an improvement in co-direction with DVA in Gross exports. Thus, the number of countries included in Clusters I and Cluster II with opposite dynamics of the combined factor and DVA in Gross exports decreased comparing to separate factor analyses matrices.



**Figure 3:** Change of DVA in Gross exports for manufacturing industries (log index change, x, 2020 to 2010) to combined change of GFCF and intermediate consumption of professional services (log index change, y, 2020 to 2010), MDAC

To gain a deeper understanding of the revealed trends for Advanced Economies, an additional chart illustrating the dynamics of both factors and DVA in Gross exports for Advanced Economies was created. Figure (4) demonstrates the dynamics of GFCF, intermediate consumption of professional services and DVA in Gross exports for Advanced Economies. During 1995-2020, there is a steady downward trend in GFCF for manufacturing industries. By the end of the period, the ratio of GFCF to DVA in Gross Exports decreased from 68% in 1995 to 47.2% in 2020. Intermediate consumption of professional services for the same period grew from 15.7% to 17.4% to DVA in Gross exports volume.



**Figure 4:** Key trends of DVA in Gross exports for manufacturing industries ("C" section except "C19" division), GFCF and intermediate consumption of professional services with trend lines in Advanced Economies (1995 - 2020).

The GFCF decline may be a result of fundamental change in both production technology (ie. IT, robotization, composites) and organizational practices. Intermediate consumption of professional services in contrast exhibits growth, but this growth cannot be sustained in the long term without sufficient investments (GFCF) in updating technologies, technological processes, and intangible assets. This is the reason to try assessing their combined effect on the DVA in Gross exports.

#### Data sources, periodisation, grouping and data cleaning, variables

##### Data sources

The study utilised data on TiVa (OECD, 2023e) and ICIO, covering the period from 1995 to 2020 (OECD, 2023a, Miller & Blair, 2022). The OECD collects and publishes this data annually, drawing on national Input-Output tables from 76 economies across 45 industries. The data is presented in OECD database in current USD.

To convert indicators in USD current prices to USD constant prices, the USA deflator was applied. The reasons for choosing this indicator as this deflator were:

- currently, two hard currencies dominate world trade: the USD (accounting for 96% of trade invoicing in the Americas, 74% in the Asia Pacific, and 79% in the rest of the world) and the Euro (predominant in Europe at 66%, largely due to intra-European settlements) (European Central Bank, 2023, Eurosai, 2024, Bertaut et al., 2023). In addition to the direct effect through dominance in invoices, the USD dominates in international banking, including international trade lending (Bertaut et al., 2023).
- the dependence of international trade on the USD is also confirmed by a number of researchers, for example Shin et al. (2021) indicate that the volume of international trade and USD currency strength have a negative correlation (a strong USD means a decrease in international trade and vice versa). The influence is exercised through the exchange rate, which affects the competitiveness of exports and the availability of working capital for exporting companies.
- the European Central Bank notes a general strengthening of the Euro share in goods and especially in international trade in services. However, it acknowledges the dollar's dominant role as the primary settlement currency, even for the foreign trade of Eurozone countries (European Central Bank et al., 2024, Schaefer, 2008).
- another reason for deflation by US deflator was that a number of studies have proven the strong influence of the real exchange rate (RER) on the competitiveness and volume of exports of countries compared to the influence of domestic inflation (ie, Ito et al., 1996).

##### Periodisation

In order to more accurately reflect the trends in GVCs and international trade the study was conducted separately for two periods (Stanley, 2023):

- from 1995 to 2008 (Liberalisation): reducing barriers to the movement of goods, investments and labour; active inclusion of central and eastern European countries in the GVCs; capacity building in Asian countries.

• from 2008 to 2020 (Slowbalization): protectionist policies and regionalization in manufacturing; stricter investment regulations, growth of the services sector in international trade. Additionally, IT and robotization emerged as significant factors, greatly impacting labour productivity, value added within GVCs and shape of GVCs.

For the selected periods, data for 2008 and 2009 was excluded because it falls within the peak of the global financial crisis. However, 2020 was included in the analysis base on the fact that the decline in trade was sharp but brief, and the recovery began quickly.

#### **Grouping and data cleaning**

The study focused on manufacturing industries ISIC Rev. 4, Section C (United Nations, 2006) excluding division C19 (Manufacture of coke and refined petroleum products), due to value added and export performance in C19 are primarily driven by commodity price volatility.

To further refine the analysis, C industries were categorized using the OECD Taxonomy of Economic Activities Based on R&D Intensity (two-digit level). We applied this grouping because in the preliminary stage of data analyses and exploratory correlation research we found that industries within different technological groups (defined by the ratio of R&D investment to value added) demonstrated varying levels of how DVA in Gross exports is influenced by investments and professional services (ie. OECD, 2016). The study initially analysed data across 76 countries. However, during data cleaning, several countries (Hong Kong, Luxembourg, Cyprus, Singapore, Ireland, and Brunei) were excluded due to outliers in GFCF and intermediate consumption of professional services. We believe that these outliers in data may be linked to tax policies associated with tax havens and preferential treatment (Damgaard & Elkjaer, 2018).

To better understand the impact and trends, countries were categorized as Advanced Economies, Emerging Market and Developing Economies (IMF, 2023). We applied this grouping because in the preliminary stage of data analyses and exploratory correlation research we revealed that the influence of GFCF and intermedia consumption of professional services on DVA in Gross exports of manufacturing industries differs significantly between these two categories of economies.

While a wide range of criteria is typically used to classify countries as Advanced Economies or Emerging Market and Developing Economies (e.g., income, institutional quality, human capital), this study adopted an IMF approach, focusing on average annual inflation rate and annual GDP growth rate to gauge initial country similarity.

Thus, this grouping made it possible to indirectly take into account inflation rate, since it is impossible to impose inflation correctly direct on DVA in Gross exports, GFCF and intermediate consumption of professional services. This methodological complexity in directly accounting for inflation arises from the fact that effects of inflation are complex and multidirectional on exporting industries, including both “push” and “pull” factors and additional influence of exchange rate fluctuations on industry performance and intermediate import.

According to our calculations based on retrospective data (World bank, 2021), both for Advanced Economies and for Emerging Market and Developing Economies demonstrate fairly stable harmonized indices of consumer prices (HCPI) within corridors typical of their respective groups.

#### **Model variables (inputs)**

Indicators used in the model (based on OECD Inter-Country Input-Output Database, TiVa):

VALU  $c,i$  (mln USD, basic prices) - annual Value Added in country  $c$  by industry  $i$  (section “C”);

VALU  $c,C$  (mln USD, basic prices) - annual Value Added in country  $c$  for all industry  $i$  (section “C”);

EXGR\_DVA  $c,i$  (mln USD, basic prices) - annual Domestic Value Added content of exports (*DVA in Gross exports*), by industry  $i$  in country  $c$  (section “C”) to all partner country/regions, represents the exported value added that has been generated anywhere in the domestic economy (i.e. not just by the exporting industry). In essence, the indicator reflects the competitiveness of both the final exporter's industry and the entire value chain within that industry in the country (OECD imf);

Consumption of VA\_M  $c,i$  (mln USD, basic prices) - annual intermediate Value Added contribution of both local and foreign professional services (section “M” - Professional, scientific and technical activities) to value added in country  $c$  by industry  $i$  (section “C”) (*intermediate consumption of professional services*).

According to ISIC rev.4 Section M “Professional, scientific and technical activities”, includes: legal and accounting activities, head offices and management consultancy activities, architectural and engineering activities; scientific research and development, advertising and market research, other professional, scientific and technical activities.

GFCF  $c,i$  (mln USD, basic prices) - annual Value Added embodied in Gross fixed capital formation (final demand) in country  $c$  by industry  $i$  (section “C”).

Gross fixed capital formation (GFCF), covers the demand for investment goods and services, by businesses and government in country  $c$ . GFCF, also called “investment”, is defined as the acquisition of produced assets (including purchases of second-hand assets), including the production of such assets by producers for their own use, minus disposals; it does not include change in inventories (OECD 2024c).



An auxiliary variable (base)  $EXGR\_DVA_{c,i,y}$  (for the first period  $y=1995$ , for the second period  $y=2010$ ) represents the effect of the export base already achieved by the country, and therefore the accumulated production assets and the starting level of consumption of professional services on results of subsequent period.

**Calculated model variables**

$SumM\_GFCF_{c,i}$  is the sum of  $GFCF_{c,i}$  and Consumption of  $VA\_M_{c,i}$ . This variable enables the evaluation of the combined impact of investments in tangible and intangible assets (resources enhancing labor productivity in terms of value added) and intermediate consumption of professional services (through developing forward and backward linkages as well as organizational innovation via outsourcing essential for increasing value added in manufacturing).

In different industries, depending on the level of technological development, as well as the stage of the industry life cycle, the ratio of GFCF and intermediate consumption of professional services differs significantly. This study assesses their cumulative impact, based on the assumption that factors proportion for every group of industries by R&D intensity is already optimal.

$$SumM\_GFCF_{c,i} = GFCF_{c,i} + Consumption\ of\ VA\_M_{c,i}$$

$shareDVA\_VA_{c,i}$  - was introduced to assess the impact of GFCF and intermediate consumption of professional services specifically on DVA in Gross exports, due to value added in industry contributes to both exports (final and intermediate) and domestic consumption (final and intermediate). The variable accounts for the influence of exogenous factors, such as exchange rate fluctuations, new trade agreements, and shifts in national economic strategy, on the  $EXGR\_DVA$  to domestic consumption ratio.

$$shareDVA\_VA_{c,i} = EXGR\_DVA_{c,i} / VALU_{c,i}$$

**The empirical model of linkages between GFCF, intermediate consumption of professional services by manufacturing industries and DVA in Gross exports of manufacturing industries**

Ordinary least squares (OLS) was used to estimate the linkages among the factors (GFCF by industries and intermedia consumption of professional services by industries – *variables of interest in the model*). The model generally performed well based on most evaluation metrics.

To enhance model robustness, countries with special tax policies associated with tax havens and preferential treatment were excluded, as detailed in the ‘Grouping and data cleaning’ section. C19 division was excluded from the model due to its high dependence from commodity prices. Additionally, the analysis was conducted for two distinct periods, 1995-2007 and 2010-2020, to reflect trends and mitigate multidirectional effects. Furthermore, separate assessments were performed for Advanced Economies, Emerging Markets and Developing Economies to account for observed behavioral differences across these groups and time periods. The model also assessed each technological group of industries based on the intensity of R&D consumption separately.

Data for each country-industry combination was analysed by the model separately for each year in the period, enabling the calculation of a weighted average for each country-industry within a given period. This approach enabled the incorporation of country-specific industry trends into the analysis.

For the purpose of the study, two empirical formulas were used. Empirical formula (1) examines the factors of GFCF and intermediate consumption of professional services concurrently.

$$Exgr\_Dva_{c,i} = \beta_0 + \beta_1 ConsM\_VA_{c,i} + \beta_2 GFCF_{c,i} + \beta_3 shareDVA\_VA_{c,i} + \beta_4 Exgr\_Dva_{c,i,y}^{y=1995|2010} + \varepsilon \tag{1}$$

Empirical formula (2) measured the combined effect of GFCF and intermediate consumption of professional services.

$$Exgr\_Dva_{c,i} = \beta_0 + \beta_1 SumM\_GFCF_{c,i} + \beta_2 shareDVA\_VA_{c,i} + \beta_3 Exgr\_Dva_{c,i,y}^{y=1995|2010} + \varepsilon \tag{2}$$

A dynamic OLS (DOLS) model was also tested on the data. However, incorporating lags and leads did not significantly enhance the model's explanatory power. In fact, the impact of the dynamic specification varied across countries and industries.

Normalization and scaling of data also did not lead to a significant improvement in the model results; therefore, these methods were not used in the final version. In our opinion, this format of presenting data without normalization and scaling data will also allow interested researchers to analyse and use the model results without requiring additional technical manuals.

The model was elaborated with Statsmodels 0.14.1 for Python and Statgraphics 18. To check the reliability of the model, standard tests included in the Statsmodels were carried out: Durbin-Watson testing revealed no significant autocorrelation.

## Findings and Discussions

The model results are presented by groups of manufacturing industries, based on OECD Taxonomy of Economic Activities Based on R&D Intensity, by periods (first period 1995-2007 and second period 2010-2020), as well as by countries groups (Advanced Economies, Emerging Markets and Developing Economies)

### Medium-low R&D intensity industries

DVA in Gross Exports at constant prices worldwide for this tech group increased by (+54.7 percentage point, pp) during the period 1995-2007. Growth ranged from (+18.2 pp) for C17-C18 industries to (+87.7 pp) for C25.

At the end of the second period, growth decelerated to (+4.5 pp). The C17-C18 group experienced a (-15.3 pp) decrease in annual terms. Notably, the C17-C18 group comprises 8.3% of the DVA in Gross Exports volume within the tech group.

Medium-low R&D intensity industries: C10-12, C13-15, C16, C17-18, C25  
Dependent variable: EXGR\_DVA

**Table 1:** Model results for medium-low R&D intensity industries group

Variable	Advanced Economies				Emerging Markets and Developing Economies			
	1995-2007		2010-2020		1995-2007		2010-2020	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
GFCF	0.1730*** (17.205)		0.0096 (1.122)		0.8116*** (7.918)		0.1615*** (19.931)	
Consumption of VA_M	0.1241*** (8.399)		0.1045*** (8.982)		1.6772*** (11.341)		-0.0211 (-0.650)	
SumM_GFCF		0.1553*** (23.234)		0.0457*** (7.670)		1.1061*** (13.778)		0.1419*** (19.720)
shareDVA_VA	-257.39 (-0.584)	-489.61 (-1.139)	-328.82 (-0.905)	59.674 (0.165)	-10990*** (-7.498)	-8640.2*** (-6.265)	-6928.6*** (-8.160)	-8231.7*** (10.096)
EXGR_VA_1995	0.8673*** (130.79)	0.8607*** (142.982)			1.6603*** (67.075)	1.7078*** (75.646)		
EXGR_VA_2010			0.9985*** (186.55)	1.0113*** (205.133)			1.2787*** (329.06)	1.2704*** (357.169)
constant	93.318** (2.611)	115.91*** (3.362)	-14.134 (-0.458)	-57.004 (-1.882)	-110.63 (-1.681)	-194.32** (-3.060)	9.4122 (0.208)	39.228 (0.870)
R-squared:	0.948	0.947	0.981	0.980	0.755	0.753	0.986	0.986
No.Observations:	2 080	2 080	1 760	1 760	2 470	2 470	2 090	2 090

Note: t-statistics in parentheses, \*\*\* p<0.001, \*\* p<0.01, \* p<0.05.

### Advanced Economies

In the first period 1995-2007, the model performed well on the variables of interest, with highly significant p-values for both (1) GFCF and ConsM\_VA, and (2) SumM\_GFCF.

Simultaneously, confidence interval of the constant exhibited significant scatter, potentially attributable to the fact that the largest economies reduced DVA in Gross exports of several medium-low industries by R&D intensity. For instance, the USA, Japan, and Germany significantly decreased DVA in Gross exports in C13-C15. Moreover, Japan reduced DVA in Gross exports in all Medium-low R&D manufacturing industries group, except C10-C12. This trend primarily impacted the constant interval due to the C13-C15 group, which comprised more than 28% of the global annual DVA in Gross exports of the group.

In the second period from 2010 to 2020, the influence of GFCF on the change in DVA in Gross exports weakened considerably and exhibited a multidirectional effect, likely contingent on a country's industrial priorities. Simultaneously, Formula (2) (combined factor) indicates a strong positive relationship, supporting the hypothesis of a partial substitution of investment (GFCF) with intermediate consumption of professional services due to the change production operating model (value chain management in manufacturing industries). This substitution facilitates the creation of backward and forward linkages for industry, thereby increasing the industry's DVA in Gross exports.

### Emerging Markets and Developing Economies

For the first period, the relationship between the variables of interest and DVA in Gross exports is strongly significant. Moreover, the impact (slope) of these variables is significantly higher than in Advanced Economies.

In the second period, the influence of GFCF diminished, but the strong relationship between the variables persisted. Conversely, the model estimates low significance of intermediate consumption of professional services. This may be connected with replacement of

intermediate consumption of imported (foreign) professional services with local cheaper professional services in some economies. The shareDVA\_VA indicator similarly reveals strong negative relationship, indicating that several economies prioritized domestic consumption over exports.

Formula (2) demonstrated a strong positive impact of SumM\_GFCF, leading us to tentatively conclude that, for the medium-low industries by R&D intensity in developing economies, the impact of GFCF on exports was more sufficient than the intermediate consumption of professional services during both the first and second periods.

### Medium R&D intensity industries

DVA in Gross exports at constant prices worldwide for this tech group increased by (+92.5pp) between 1995 and 2007, growth ranged from (+62.4pp) for C23 industry to (+115.8pp) for C24.

Based on the results of the second period (2010-2020), medium R&D intensity industries showed a near-zero growth rate (+0.1pp). The C24 industry experienced a decrease of (-20.5pp) to level of 2010 - it constitutes a significant share of the groups DVA 37% in 2020. The highest growth during this period was achieved by C31-33, with a (+24.4 pp) increase since 2010.

Medium R&D intensity industries: C22, C23, C24, C31-33

Dependent variable: EXGR\_DVA

**Table 2:** Model results for medium R&D intensity industries group

Variable	Advanced Economies				Emerging Markets and Developing Economies			
	1995-2007		2010-2020		1995-2007		2010-2020	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
GFCF	-0.0896*** (-6.989)		-0.0706*** (-6.201)		0.8991*** (12.200)		0.5327*** (15.087)	
Consumption of VA_M	0.6476*** (13.290)		0.4516*** (10.884)		4.1169*** (26.392)		1.6203*** (24.488)	
SumM_GFCF		0.0399*** (4.946)		0.0195* (2.482)		1.5345*** (21.882)		0.6525*** (17.386)
shareDVA_VA	-2520.1** (-3.185)	354.97 (0.448)	-6.9174 (-0.123)	7.4483 (0.128)	-2939.3*** (-4.466)	-961.56 (-1.371)	-668.15 (-0.567)	1495.2 (1.176)
EXGR_VA_1995	0.9579*** (0.011)	1.0278*** (99.560)			1.1517*** (50.317)	1.1999*** (48.843)		
EXGR_VA_2010			0.8584*** (125.34)	0.8934*** (143.41)			1.0660*** (75.684)	1.1380*** (78.053)
constant	237.20*** (3.896)	47.3793 (0.767)	142.9619*** (4.010)	154.17*** (4.165)	-82.979* (-2.055)	-119.03 (-2.731)	-234.80*** (-3.632)	-296.27*** (-4.232)
R-squared:	0.894	0.883	0.950	0.945	0.751	0.709	0.945	0.935
No.Observations:	1664	1664	1408	1408	1976	1976	1672	1672

Note: t-statistics in parentheses, \*\*\* p<0.001, \*\* p<0.01, \* p<0.05.

### Advanced Economies

In both periods (1995-2007 and 2010-2020), the model demonstrated strong results for GFCF and intermediate consumption of professional services, as indicated by low p-values.

GFCF exhibited a robust negative correlation with DVA in Gross exports, whereas intermediate consumption of professional services had a positive impact.

The negative relationship between GFCF and DVA in Gross exports persisted in the **second period**, while the positive influence of M-total consumption slightly diminished. Among the largest Advanced Economies (for example, Germany, USA, Japan) there was

a significant reduction in DVA in their manufacturing exports at constant prices. This may be connected with relocation of manufacturing facilities to neighbour economically integrated countries (i.e. USA companies relocated C31-C33 to Mexico (+21.2 pp) DVA in Gross exports in 2020 to 2010; Germany relocated C22 to Poland (+56.2pp) DVA in Gross exports, Hungary (+28.8pp) and Czech Republic (+12.6pp).

Formula (2) confirms the hypothesis that GFCF is substituted with intermediated consumption of professional services to drive DVA in Grow export growth in the first period, with a strong positive relationship. This positive relationship persists in the second period too.

### **Emerging Markets and Developing Economies**

The relationship between the variables of interest and DVA in Gross exports was very strong during the first period. Notably, intermediated consumption of professional services exerted a significantly greater influence compared to Advanced Economies. This positive relationship between the variables persisted in the second period.

### **Medium-high R&D intensity industries**

DVA in Gross exports at constant prices worldwide for this tech group increased by (+70.4pp) between 1995 and 2007 Growth ranged from (+56.9pp) for C28 industries to (+91.7pp) for C30.

At the end of the second period, this group experienced a near-zero decline of (-0.1pp) (2020 to 2010). Industry C30 decreased by (-16.2pp), while C27 grew by (+20.3pp). Combined share of the declining industries (C28, C29, C30) reached 61.5% in 2020.

Medium-high R&D intensity industries: C20, C27, C28, C29, C30

Dependent variable: EXGR\_DVA

**Table 3:** Model results for medium-high R&D intensity industries group

Variable	Advanced Economies				Emerging Markets and Developing Economies			
	1995-2007		2010-2020		1995-2007		2010-2020	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
GFCF	-0.0246*** (-3.655)		-0.0210** (3.123)		0.0617*** (12.064)		-0.0156*** (-5.056)	
Consumption of VA_M	0.8585*** (15.951)		0.6910*** (11.824)		3.2421*** (35.818)		0.7515*** (11.843)	
SumM_GFCF		0.0064 (0.933)		0.0247*** (4.400)		0.1809*** (40.320)		0.0048 (1.837)
shareDVA_VA	-2851.2* (-2.343)	2841.9* (2.306)	300.5178 (0.291)	3673.9*** (3.581)	-2996.2*** (-6.688)	614.47 (1.167)	-7249.9*** (-7.462)	-4834.3*** (-4.930)
EXGR_VA_1995	0.9692*** (90.750)	1.0582*** 109.76			1.1849*** (44.700)	1.527*** (51.498)		
EXGR_VA_2010			0.9273*** (136.63)	0.9726*** (170.10)			1.3324*** (92.036)	1.4452*** (128.89)
constant	378.32** (2.943)	-95.089 -0.718	40.139 (0.342)	-233.34* (-1.959)	46.885 (1.595)	-137.45*** (-3.931)	78.4417 (1.097)	-99.842 (-1.384)
R-squared:	0.942	0.935	0.975	0.973	0.811	0.723	0.949	0.946
No. Observations:	2080	2080	1760	1760	2470	2470	2082	2082

Note: t-statistics in parentheses, \*\*\* p<0.001, \*\* p<0.01, \* p<0.05.

### **Advanced Economies**

During the first period, the model showed promising results for the intermediate consumption of professional services. Negative relation of GFCF to to DVA in Gross export that may be connected with relocation of manufacturing facilities from Advanced Economies to neighbour economically integrated countries. For instance, due to possible relocation of German production facilities, DVA in Gross exports surged by (+214pp) in Poland (+143pp in GFCF), (+473pp) in the Czech Republic (+124pp in GFCF), and (+386pp) in Hungary (+91pp in GFCF). Conversely, these countries experienced a slowdown in DVA in Gross exports during the

second period, and the region's industrial leader, Germany, recorded a DVA in Gross exports decline of (-12 pp) by 2020 relative to 2010. Formula (2) doesn't indicate dependence between GFCF and intermediated consumption professional services to DVA in Gross exports through in the first period. Correlation strengthens in the second period.

### **Emerging Markets and Developing Economies**

The relationship between the variables of interest and DVA in Gross exports was very strong during the first period, with intermedia consumption of professional services significantly outpacing GFCF in slope. In the context of a global decline in DVA in Gross exports during the second period, GFCF exhibited a negative impact while maintaining a robust relationship. Although slope of intermedia consumption of professional services decreased, its positive relationship persisted.

### **High R&D intensity industries**

DVA in Gross exports at constant prices worldwide for this tech group increased by (+64.6 pp) between 1995 and 2007, with industry C21 registering a (+173.3pp) growth and C26 showing a (+50.4pp) increase.

At the end of the second period (2010-2020), high R&D intensity industries group experienced a (+16.4pp) growth (2020 compared to 2010). Industry C21 expanded by (+24.8pp), while C26 grew by (+14.3pp). In 2020, C26 accounted for approximately 78.5% of DVA in Gross exports within this group.

High R&D intensity industries: C21, C26

Dependent variable: EXGR\_DVA

**Table 4:** Model results for high R&D intensity industries group

Variable	Advanced Economies				Emerging and Developing Economies			
	1995-2007		2010-2020		1995-2007		2010-2020	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
GFCF	-0.0722*** (-4.152)		-0.2034*** (-10.729)		1.7591*** (29.817)		0.4884*** (17.981)	
Consumption of VA_M	1.0132*** (12.871)		0.5011*** (6.158)		6.4721*** (18.416)		1.0616*** (10.541)	
SumM_GFCF		0.0725*** (5.289)		-0.081*** (-9.273)		2.2394*** (47.750)		0.5259*** (19.653)
shareDVA_VA	-1484.99 (-0.927)	2638.9 (1.555)	-1076.5 (-1.468)	-196.96 (-0.263)	-6730.5*** (-4.662)	-2450.09 (-1.633)	-1879.8* (-2.299)	-1174.2 (-1.429)
EXGR_VA_1995	0.8386*** (52.075)	0.7946*** (46.709)			0.1012 (1.241)	0.0170 (0.195)		
EXGR_VA_2010			1.0366*** (107.64)	1.0457*** (105.75)			0.9994*** (64.951)	1.0321*** (71.425)
constant	749.66** (3.258)	835.91*** (3.351)	71.378 (0.445)	127.87 (0.770)	-52.699 (-0.415)	-178.82 (-1.317)	-226.99 (-1.941)	-230.55 (-1.937)
R-squared:	0.935	0.923	0.965	0.963	0.835	0.810	0.989	0.988
No. Observations:	832	832	704	704	988	988	836	836

Note: t-statistics in parentheses, \*\*\* p<0.001, \*\* p<0.01, \* p<0.05.

### **Advanced Economies**

The model demonstrated robust results for the intermediate consumption of professional services in both periods. Notably, the variable's influence was significantly higher in the first period compared to industries with less R&D intensity industry groups. In the second period, the slope for intermediate consumption of professional services decreased by more than half.

GFCF exhibited a consistent, moderate negative relationship with DVA in Gross exports throughout both periods. This correlation likely stems from the ongoing rapid depreciation, obsolescence, and technological advancements that continually reshape the demand for GFCF.

Formula (2) reveals a strong negative relationship between GFCF and intermediated consumption professional services to DVA in Gross exports during the second period, potentially attributable to strategic investments and a focus on R&D and services, which may not yield rapid DVA in Gross exports growth in the short term. This pattern is exemplified by the USA and South Korea within the C26 sector. While USA GFCF increased by (+5.1%) in this industry and professional services consumption surged by (+75%) in 2020 compared to 2010, DVA in Gross exports declined by (−30.5%). Similarly, Korea experienced a (+54%) GFCF growth but a (−7.6%) decrease in DVA in Gross exports.

#### ***Emerging Markets and Developing Economies***

The relationship between the variables of interest and DVA in Gross exports was exceptionally strong during the first period, with services exhibiting the highest slope value among all groups by R&D intensity (slope: 6.47). While this strong relationship persisted in the second period, the positive impact of the variables, particularly intermediate consumption of professional services, diminished.

#### **Discussion**

For Advanced economies our model shows sustainable results, showing a trend towards a decrease in the influence of investments (GFCF) on value added in gross exports in Medium, Medium-High and High R&D intensity manufacturing industry groups. Given that value added in gross exports also shows a stable high relationship with changes in the consumption of professional services, we consider that there is a substitution of investments in industry with the consumption of professional services. This is a systemic and multifactorial phenomenon associated with the upgrading, servitization of manufacturing, and changes in global value chains.

Nevertheless, there remains much room for scientific discussion and subsequent research on the joint influence of investment consumption (gross fixed capital formation, or GFCF) and intermediate consumption of professional services in industrial sectors. In our opinion, it is most interesting to study this effect using the example of industries covering full value added chains, rather than individual stages of production of final industrial products. These studies can be carried out at the level of individual countries, groups of countries, and individual value chains.

#### **Conclusions**

Despite the overall growth of both GFCF and DVA in Gross exports of manufacturing industries achieved in the first period (2007 to 1995), the model reveals an emerging trend towards a declining GFCF-to-DVA in Gross exports ratio in most *Advanced Economies* across Medium, Medium-High and High R&D intensity manufacturing industry groups. This is evidenced by a predominantly negative relationship between GFCF and DVA in Gross exports in most annual periods. As previously discussed, this may reflect the development of new production technologies and the adoption of technological and organizational innovations, relocation of production facilities that reduce the reliance on GFCF in terms of volume. The economic downturns of 1997-1998 and 2001-2002 significantly accelerated this emerging downward trend in GFCF-to-DVA in Gross exports ratio. This emerging trend coincided with a robust growth in intermediate consumption of professional services by manufacturing industries across annual data and total results of the whole observed period.

Between 2010 and 2020, the previously observed emerging trend of diminishing importance of GFCF consolidated. At the end of the decade, GFCF in relation to DVA in Gross exports showed a negative slope across Medium, Medium-High and High R&D intensity manufacturing industry groups. As for the Medium-low group the model reflected low significance due to multidirectional dynamics across countries. This trend was particularly pronounced by *Advanced Economies* with clear technological leadership in manufacturing (USA, Germany, Japan), where the development of production technologies, the introduction of technological and organizational innovations, have reduced the need for GFCF in terms of volume.

Additionally, in second period (2010-2020) the model showed that slope of intermediate consumption of professional services to DVA in Gross exports growth diminished compared to the first (1995-2007) period. This decline was influenced by fundamental factors such as a general slowdown in global trade, which curtailed potential growth. Furthermore, the economic downturns of 2016-2017 and 2020 further shaped the overall trend.

We are satisfied with the results of assessing the combined and simultaneous impacts of GFCF and intermediate consumption of professional services on DVA in Gross exports for manufacturing industries (Formula (2)). The model reflects the partial substitution of GFCF with intermediate consumption of professional services in *Advanced Economies* due to the change of production operating model (value chain management in manufacturing industries), which is proved by high influence of this combined factor on the DVA in Gross exports. This substitution facilitates the upgrading of value chain by creation of backward and forward linkages for manufacturing industries.

At the same time the observed decline in the share of GFCF volume to DVA in Gross exports (especially across Medium, Medium-High, and High R&D intensity manufacturing industries) suggests a potential paradigm shift in *Advanced Economies'* production operating models. The increase in DVA in Gross exports attributable to an increased intermediate consumption of professional services can only partially explain the phenomenon. Without considering the trends and impacts of investments in technology development and technological and organizational innovation, the positive effect of professional services on DVA in Gross exports growth in manufacturing industries might be overestimated. To fully understand this complex relationship, further cross-industry and cross-country analyses using TIVA, national, and firm-level data are warranted.

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