On GVC and Innovation: What is at Stake?[1]

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Abstract

This paper empirically investigates the impact of global value chains (GVC) participation on countries' innovation performance. Highlighting the learning effect of foreign knowledge embedded in imported intermediate goods counters the argument that GVC participation is biased towards developed countries with skilled labor abundance. We construct a GVC knowledge spillovers index by merging data on GVC from the EORA26 dataset with R&D of the trade partner. Results show a positive and significant effect of the GVC knowledge spillovers index on innovation measured by resident patent per capita. Likewise, we show that the quality of institutions, intellectual property agreements, competition policy and trade policy constitute a pile of interfering preconditions in the nexus between GVC participation and innovation. Our results remain robust when we use an instrumental variable approach to control for the endogeneity between GVC and innovation and when we use alternative measure for our two variables of interest.

Keywords: Global Value Chains; innovation; R&D; technological change.
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1. Introduction

In recent years, the mounting trend of global value chains (GVC) participation has slowed due to global investments accompanied with the absence of major liberalization initiatives (World Bank, 2020). The "slowbalization" wave is further augmented by the aftermath of COVID-19 pandemic crisis witnessing deliberate decoupling to unbind the interdependence between industries and countries and therefore prevent the domino effect stirring in crises (Coveri et al., 2020). In this respect, studying the benefits of outsourcing at the country level is crucial to scrutinizing the tradeoff of "reshoring" activities. Beside the conventional theories emphasizing the gains of GVC participation in terms of trade (Feenstra and Hanson, 1996; Grossman and Rossi-Hansberg, 2008; Baldwin, 2013), trade in value added is indeed advantageous in terms of other facets. This paper studies the impact of GVC participation on innovation.

The nexus between trade in final goods and innovation is broadly reviewed (Keller, 2004; Alessandria et al., 2021; Ackigit and Melitz, 2021). Yet, GVC participation is also likely to have a knowledge driven effect since backward participation linkages to GVC transmit embedded foreign knowledge to destination countries that can be signaled by countries' innovation performance. Aslam et al. (2018) argue that, between 1995 and 2003, foreign knowledge enhanced productivity growth by 0.4% and the former led to more than doubling domestic productivity in developing countries between 2004 and 2014. Undeniably, the gains of international fragmentation of production in terms of technological spillovers are still subject to empirical exploration. While our study highlights the impact of backward linkages to GVC participation on innovation, results emphasize the potential prospect for developing countries in realizing innovation driven economic growth[4].

Using the simple[5] offshoring definition, we synthesize the gains of GVC participation in terms of innovation by empirically estimating the impact of GVC knowledge spillovers on resident patent per capita. Auxiliary interfering factors in the GVC learning effect are empirically explored namely business environment, institutions, world trade organization (WTO) membership, intellectual property rights (IPRs) agreements, trade policy and competition policy. Indeed, foreign knowledge spillovers are particularly central for developing countries disadvantaged in technology production. On a flipside however, the learning effect of GVC participation is constrained by prevalent mitigating conditions. First, developing countries are underprivileged with rule of law as a subfactor of institutions' quality. Second, strengthening IPRs through Trade Related Aspects of Intellectual Property Rights (TRIPS)[6] trade agreement is argued to be biased towards higher income countries exporting technology. Third, unapt non-tariff trade costs in developing countries discourages foreign exporters of technology (UNCTAD, 2022) and consequently hinders foreign knowledge spillovers. Fourth, lax competition policy disincentivizes innovation (Goto, 2009). Against this background, disentangling the impact of the stated preconditions is crucial to pledging the learning effect of GVC participation. We contribute to the existing literature by studying the

[4] Economic growth is either factor driven, investment driven, or innovation driven (Raghupathi and Raghupathi, 2019). The share of innovation driven growth accounts to more than 50% of economic growth drivers (OECD, 2005; Kayal, 2008).

[5] The simple definition is limited to intermediate goods' crossing borders at least once. The complex definition of vertical specialization guarantees the reexporting of intermediate imports.

[6] Article 31 in the amended agreement provides WTO members with special licenses to produce and export medicines to other members having insufficient domestic production.

multifactorial mitigating dynamism, which is novel to the empirically reviewed nexus between GVC and innovation. Results show a positive and significant effect of the GVC knowledge spillovers index on innovation. Moreover, we show that the quality of institutions, intellectual property agreements, competition policy and trade policy constitute a pile of interfering preconditions in the nexus between GVC participation and innovation. Our results remain robust when we use an instrumental variable approach to control for the endogeneity between GVC and innovation and when we use alternative measure for our two variables of interest.

This paper is composed of six sections structured as follows: Section 2 reviews the literature on GVC and innovation. Section 3 presents stylized facts and data trends in different income groups within the period of our study (1990-2019). Section 4 explains the econometric specification and describes the data. Section 5 is dedicated to the empirical results of the effect of GVC knowledge spillovers on resident patent per capita in a panel of 83 countries over a time span of 30 years. Section 6 concludes and offers policy implications to the end of fostering innovation particularly in lower-middle income countries.

2. Literature Review

The effect of GVC knowledge spillovers on domestic innovation is addressed by blending two strands of literature. The first strand summarizes the association between GVC and domestic innovation, whereas the second strand is related to measuring knowledge spillovers and endogenizing innovation.

A wide strand of the literature focuses on value creation through trade in intermediate goods (Johnson and Noguera, 2012; Antràs and Chor, 2013; Castellani et al., 2015; Aichele and Heiland, 2018; Lee and Yi, 2018). Beside the decrease in marginal cost resulting from specialization, increased production due to GVC participation can be rationalized by increased productivity resulting from technological changes channeled through imports of intermediate goods (Grossman and Helpman, 1991; Schmidt, 1997; Kasahara and Rodrigue, 2008). Despite the conventional concern of the possible adverse effect of GVC participation on developing countries in terms of the relative wages of low skilled labor (Kaplinsky, 2000 and Rodrik 2018), a number of studies emphasize that intermediaries' trade generates learning and innovation activities (Schmitz and Knorringa, 2000; Gereffi et al., 2005; Giuliani et al., 2005) leading to technological change. Notably, the transfer of technological knowledge through GVC is governed by the nature of the relationship and the distance among GVC participants (OECD, 2017).

Thus, GVC participation can play a crucial role in international knowledge and innovation sharing. Indeed, industry's performance in GVC enhances innovation (OECD, 2013 a and b) since the quality of products is deliberately upgraded to face the demand of foreign supply chains. However, the estimated positive impact depends chiefly on absorptive capacities of the destination country (Corrado et al., 2013). Primarily, developing countries' GVC participation is deterred by a handful of obstacles rooted in persistent preconditions and strategic behavior (Bell and Albu, 1999; Schmitz, 2004). Likewise, a noteworthy stream in literature argues that the degree of upgrading in GVC is endogenous to the nature of home institutions (Werner, 2012; Barrientos et al., 2016; Pipkin and Fuentes, 2017; Kano and Tsang, 2020), and the business environment (Dovis and Zaki, 2020). Arguably, the mitigating effect of weak institutions can eventually be alleviated by gaining

knowledge through enhanced GVC participation (Kano, 2018). Fortunately, digitalization has recently facilitated GVC participation particularly in developing countries facing high trade costs and prohibitive conditions (World Bank, 2020).

Importing intermediate goods is a channel for technological change due to the potential for foreign knowledge spillovers (Keller, 2002 and 2004). Although knowledge is tacit and difficult to measure, imported value-added embed spillovers that can be mirrored in foreign R&D stock endowed in partner countries that export intermediate goods (Coe and Helpman, 1995; Maskell and Malmberg, 1999; Cowan and Jonard, 2004; Zhang, 2020). Empirically, a rich strand of literature examined international knowledge diffusion across countries (Coe and Helpmann, 1995; Eaton and Kortum, 1999; Gong and Keller, 2003; Keller, 2004; Bottazzi and Peri, 2007; Coe et al., 2009; Bloom et al., 2013; Malerba et al., 2013; Bloom et al., 2016). While few results imply a negative short-run effect of GVC participation on innovation in countries with low absorptive capacity (Pietrobelli, 2008 and Farole and Winkler, 2014), other studies find conflicting results. Indeed, the nexus between GVC and innovation is empirically tested using various cross-sectional regressions for developing countries, such as Gehl Sampath and Vallejo (2018) who find that innovation interacts with GVC to foster learning and technological upgrading at the country level. Similarly, the positive effect of GVC participation on innovation is empirically recognized for European countries relying on the WIOD dataset (Tajoli and Fellice, 2018).

A comprehensive body of literature endogenized innovation using patent per capita (Scotchmer and Green, 1990; Horowitz and Lai, 1996; O'Donoghue and Zweimuller, 2004; Bottazzi and Perri, 2007; Bloom et al., 2013; Malerba et al., 2013; Tajoli and Fellice, 2018). According to the conceptual innovation framework, R&D personnel and expenditures are inputs to innovation, whereas patenting is the indicator of knowledge creation (Raghupathi and Raghupathi, 2019). While patenting is a direct innovation measure, it can underestimate knowledge creation for two reasons. First, several goods are unpatentable due to their intangible nature (Corrado et al., 2013). Second, although patenting is associated with higher firms' exports (Aghion et al, 2018), some inventors intentionally follow trade secrets' strategies as a substitute to patenting aiming at preserving their competitive advantage (Crass et al., 2019). Recent variations in domestic patenting activities across countries is justified by different level of development, size of country, and R&D (WIPO, 2021). In the same vein, the literature on trade and innovation highlights the correlation between trade policy and patents since higher tariff rates for example, negatively affect patents for developed and developing countries alike (Vishwasrao et al., 2007). Likewise, the effect of non-tariff measures (NTMs) is of particular importance in countries of the South where infrastructure deficiency augments trade costs (Beghin et al., 2015). Indeed, a harmonized set of trade policy regulations minimizes mismatches leading to positive externalities' diffusion of GVC in information, communication, and technology (ICT) goods (Ghodsi et al., 2021).

Although developing countries have a technological change opportunity by absorbing knowledge spillovers resulting from linking economies through GVC integration (Mudambi, 2008), knowledge transmission is constrained by a pile of prevalent conditions (Ghallini and Wright, 1990). First, innovation catchup necessitates institutional change (Buckley et al., 2020). The share of locally sourced inputs through foreign investors is largest in countries with strong rule of law (Amendolagine et al., 2019) given that complex products require strong institutions (Karam and Zaki, 2019). Second, appropriate IPRs orchestrate the positive effect of GVC participation on

innovation (Ali and Rouvinen, 2015) as they protect investors' rights. Third, oil dependence induces mitigating conditions to innovation (Namazi and Mohamadi, 2018) since the economies are highly concentrated in extractive industries with a limited value-added. Fourth, competition incentivizes innovation (Marshall and Parra, 2019) whilst competition legislation and effectiveness are middling in Arab countries (Youssef and Zaki, 2022).

In light of the summarized theoretical and empirical strands of literature, this paper contributes to the recognized research gap in two respects. First, our dataset includes central beneficiaries namely lower-middle and low-income countries that are excluded from previous studies despite their technological disadvantage. Second, our identification strategy incorporates the multifactorial dynamism interfering in the GVC and innovation nexus, which is novel to the literature.

3. Stylized Facts

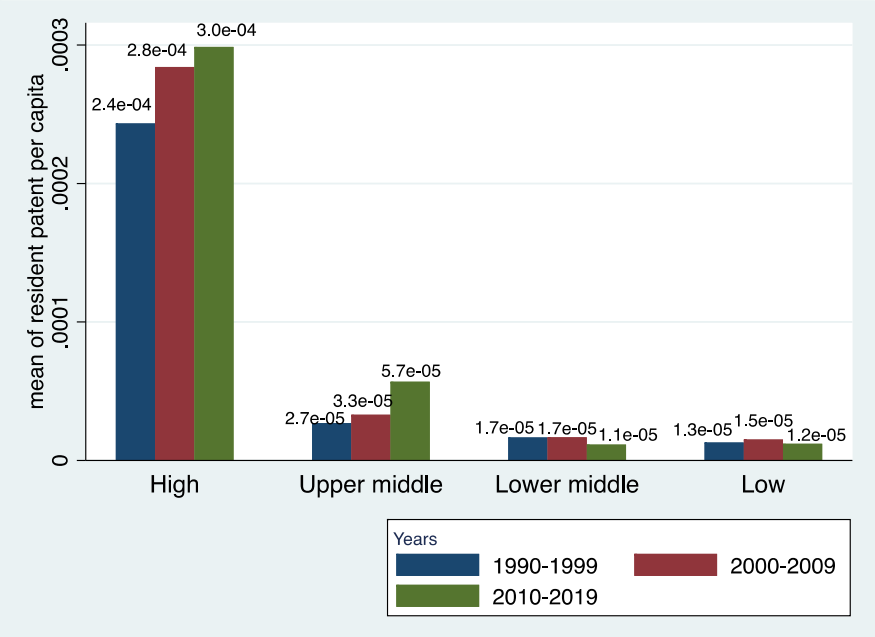
Testing the hypothesis that GVC participation stimulates domestic innovation is grounded on three stylized facts. First, innovation is spatially concentrated. Second, imported value added embed foreign knowledge to destination countries. Third, a pile of mitigating conditions interferes in the GVC knowledge spillovers effect. In this section, each stylized fact is analyzed and supported by data.

3.1 Innovation is spatially concentrated

Despite the free movement of factors of production, innovation is nevertheless clustered in high-income countries (Marshall, 1890; Jaffe and Trajtenberg, 1999; Gassler and Nones, 2008). Figure 1 presents the vast discrepancies in domestic innovation measured by resident patent per capita between high- and subsequent income- groups[7]. Throughout the last three decades, high-income countries are the front-runners of innovation with prolonged positive innovation growth rate across decades. Upper middle-income group has exceptionally experienced the highest growth rate percentage of 72% solely during the last decade compared to a 22.2% in the preceding decade. As an opposite pattern, both lower-middle and low-income groups experienced a negative innovation growth rate on average during the last decade compared to a stagnant innovation growth in lower-middle income group and a 15.3% increase in low-income group in the preceding decade.

[7] A list of countries with the corresponding income group is available in Appendix 1.

Fig. *1* Resident patent per capita - by income groups



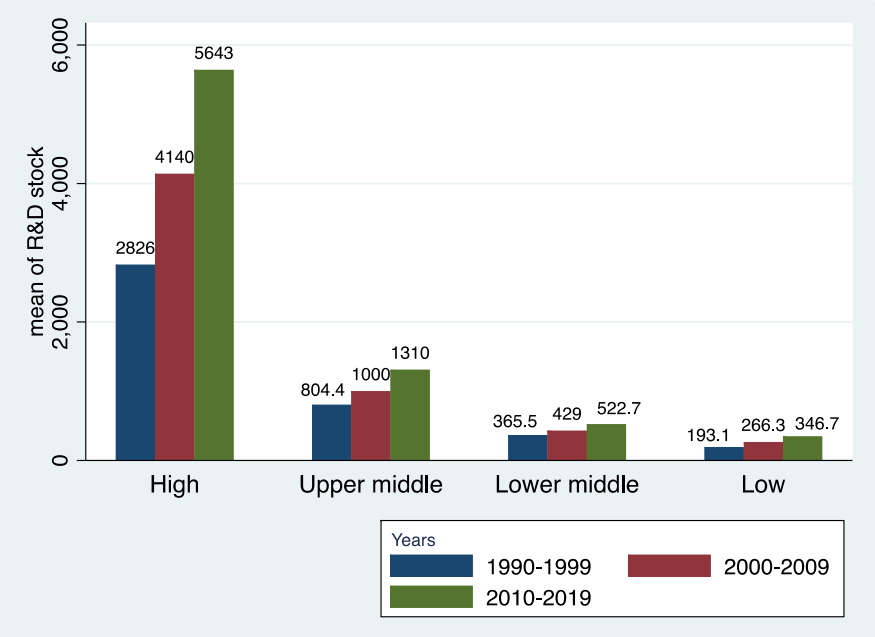
Source: Own construction based on WDI dataset

3.2 Imported value added embed foreign knowledge

Tacit knowledge embedded in imported intermediaries is a potential innovation channel for technology disadvantaged income groups. Although knowledge is intangible and difficult to measure, its foremost description that makes it measurable is its embeddedness in human capital depicted in R&D stock. Knowledge spillovers to destination (importing) countries are signaled by R&D stock located in origin (exporting) countries. As it is shown in Figure 2, during the previous decade, high-income is 4.3, 10.8, and 16.3 times richer in R&D stock on average than upper middle, lower-middle and low-income groups respectively. The discrepancies highlight the opportunity for developing countries to absorb foreign knowledge provided sufficient engagement in international production networks. Figure 3 presents the average GVC knowledge spillovers index (GVCRD[8]) in different income groups from 1990 until 2019.Clearly, the less the countries' endowment with domestic R&D stock, the higher the knowledge spillovers through GVC participation. Indeed, GVCRD is highest at low-income and decreases at higher levels of income.

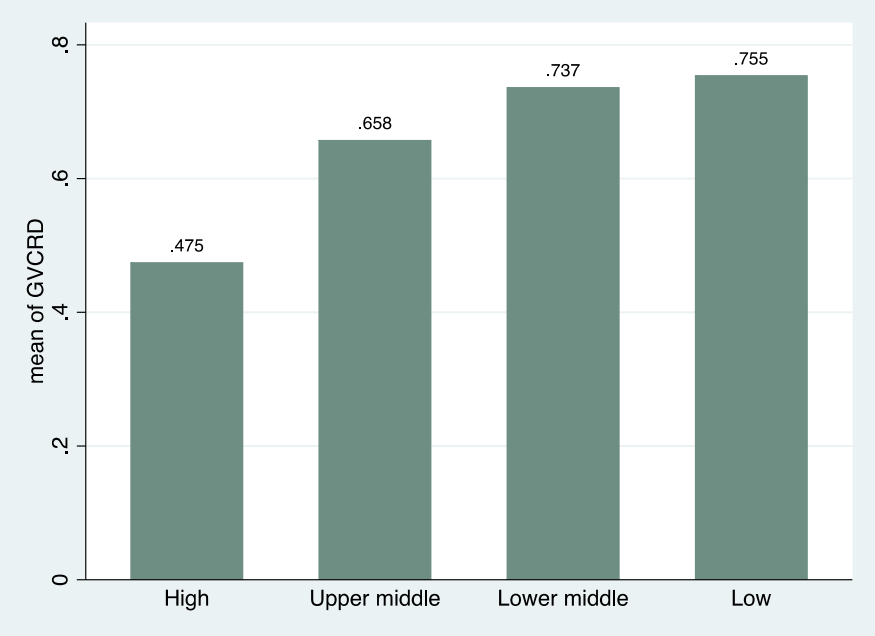
[8] Measurement details are provided in section 4.

Fig. 2 R&D stock (per million of the population) - by income groups



Source: Own construction based on WDI dataset

Fig.3 GVC knowledge spillovers index - by income groups



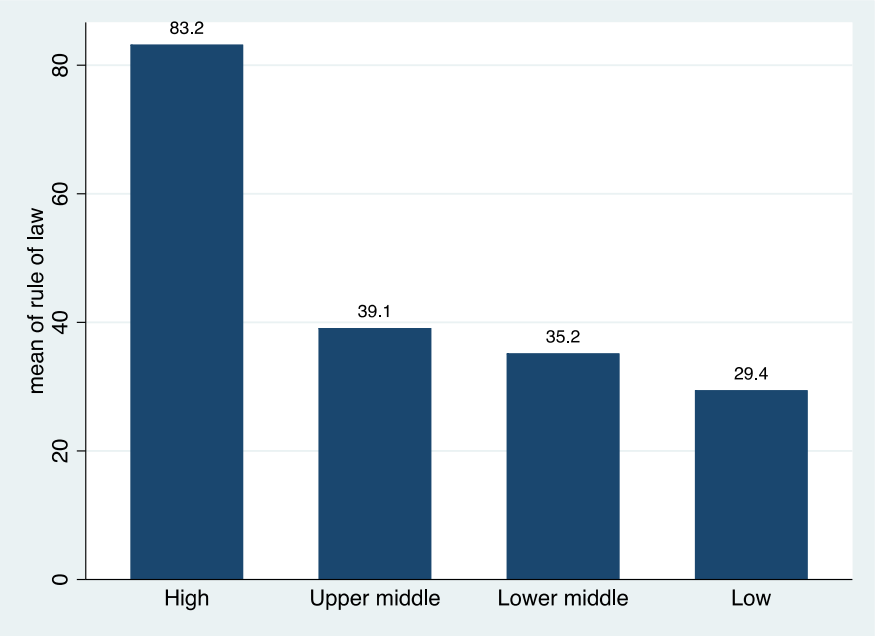
Own calculations based on merging EORA26 and WDI datasets

3.3 Knowledge spillovers' preconditions

As mentioned in section 2, a pile of conditions interferes in the nexus between GVC and innovation including rule of law, IPRs, trade policy, and competition policy. Figure 4 presents the rule of law index for different income groups and shows that rule of law is substantially higher, on average,

at high-income compared to subsequent income groups.

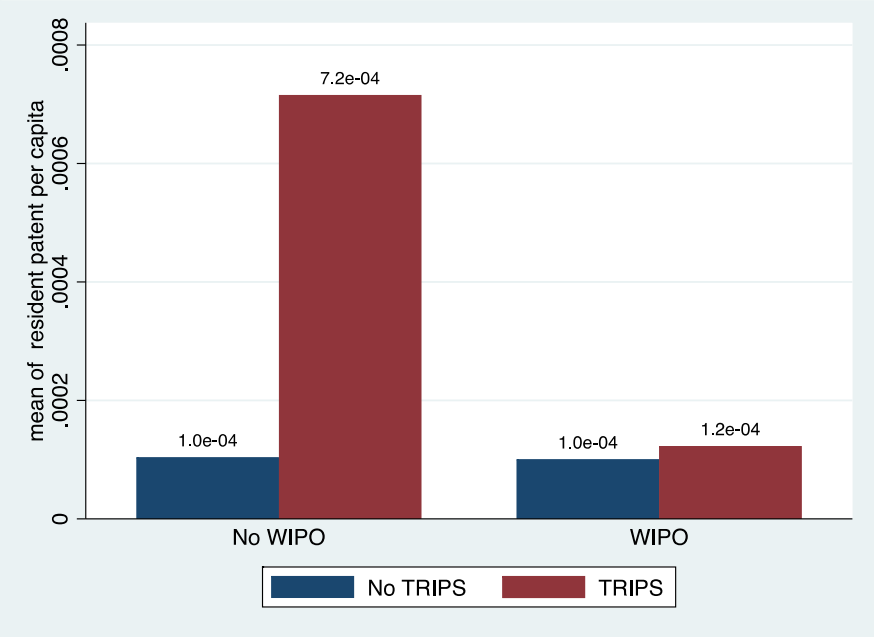
Fig. 4 Rule of law across income groups



Source: Own calculations based on World Governance Indicators Datasets

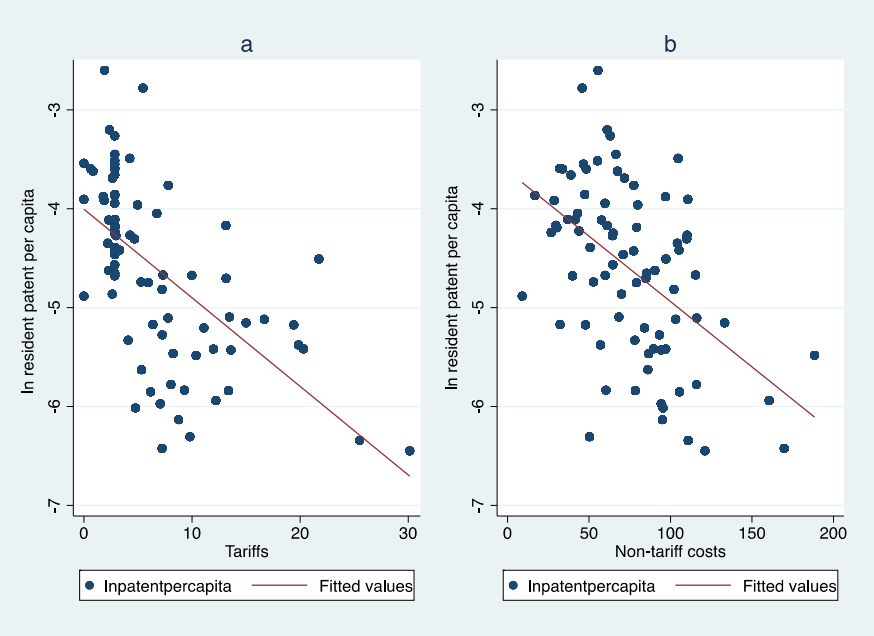
Figure 5 presents resident patent per capita against two IPRs agreements namely the World Intellectual Property Organization (WIPO) and TRIPS trade agreement. Data evidence conflicting trajectories of the two agreements in incentivizing innovation. In fact, countries involved in TRIPS exclusive of WIPO are achieving seven times higher resident patent per capita on average than countries involved in both WIPO and TRIPS. Figure 6 presents country average resident patent per capita against trade policy. Figure 6a shows negative association between resident patent per capita and tariffs. Likewise, Figure 6b shows negative association between the former and non-tariff costs pointing out to what extent trade policy might matter for innovation. Figure 7 presents country average resident patent per capita against competition proxied by the effectiveness of anti-monopoly law index showing a positive association between the two variables.

Fig. 5 Resident patent per capita against intellectual property rights agreements



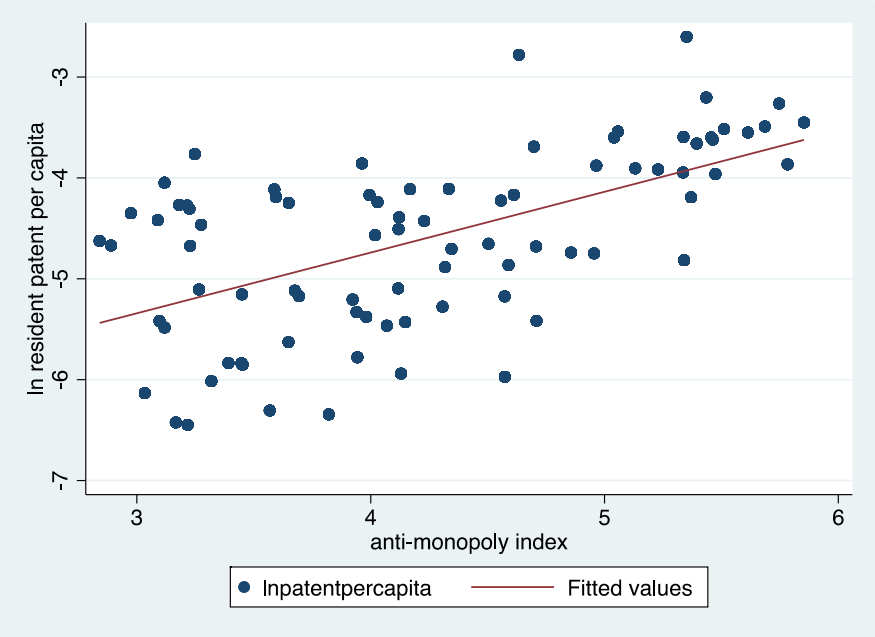
Source: Own calculations based on World Bank Deep Trade agreements' and WIPO Datasets

Fig. 6 Country average resident patent per capita against trade policy



Source: Own calculations based on WDI and ESCAP-World Bank Datasets

Fig. 7 Country average resident patent per capita against competition policy



Source: Own calculations based on WDI and Global Competitiveness World Economic Forum Datasets

Note: Figures are averaged the period 1990 till 2019

In a nutshell, while GVC might matter for innovation, this effect depends on the set of initial conditions that prevail in the receiving countries. This is why econometric modelling is necessary to capture the effect of each precondition on innovation along with its interaction with GVC.

4. Methodology and Data

Following Tajoli and Felice (2018), our econometric model estimates the effect of GVC knowledge spillovers on resident patent per capita. From numerous GVC definitions, the Feenstra and Hanson (1996) offshoring indicator[9] is used in measuring the variable of interest. To construct this variable, the input output value added tables in EORA26 database[10] (Johnson, 2018; Lenzen et al., 2012 and 2013) is merged with R&D data. Thus, the variable we construct (GVCRD) is the share of foreign knowledge weighted value added absorbed in the total knowledge weighted value added. Hence, for each destination (importer) country, value added imported from an origin country is multiplied by the corresponding R&D stock in the origin country. Then, the summation is divided by the total R&D weighted value added including the domestic value added as follows:

$$\text{GVCRD}it = \frac{\sum_i^t VA\ ijt * RDjt}{(\sum_i^t VA\ ijt * RDjt) + (DVAit * RDit)} \qquad (1)$$

where i is the destination (importing) country, j is the origin (exporter) country, t is time in years,

[9] Share of foreign value added absorbed through imported intermediate goods to the total value added of intermediate goods including the domestic value added.

[10] The database includes 189 countries from 1990 till 2019. All countries are aggregated to a common 26 sector classification.

VA is the imported value added, DVA is the domestic value added, and RD is the R&D stock[11].

Using fixed effects regression, our model aims at estimating the foreign learning effect of backward participation linkages to GVC participation. Our contribution to the original model is twofold. First, we rely on the EAORA26 in constructing the GVC knowledge spillovers index allowing for the inclusion of lower-middle and low-income countries. To our knowledge, this is the first paper using the EORA26 dataset in constructing a GVC knowledge spillovers measure. Second, we expand the identification to include interfering variables in the nexus between GVC and innovation. In particular, we account for the interaction between domestic R&D stock and GVCRD, business environment, WTO membership, the quality of institutions, IPRs agreements, trade costs and competition policy. Equation (2) presents the baseline model specification.

$$PAT_{it} = a_0 + a_1\, GVCRD_{it} + a_2\, X_{it} + u_i + \varepsilon_{it} \qquad (2)$$

where,
PAT_{it} is the resident patent per capita in country i at year t and is expressed in logarithm, $GVCRD_{it}$ is the GVC knowledge spillovers index in country i at year t. X_{it} is a set of control variables including domestic R&D stock expressed in logarithm, GDP per capita controls for country's level of development and is expressed in logarithm, total population measures the size of the country and is expressed in logarithm. Moreover, we include the share of oil exports in merchandise exports as a measure of resource dependence, time to enforce contracts as a measure of business environment, WTO membership (dummy variable equals to 1 if the country is a member of the WTO and 0 otherwise), and rule of law as a proxy of the quality of institutions. u_i is a time invariant fixed effects controlling for cross countries' unobserved heterogeneity. ε_{it} is the error term.

As it was mentioned before, we are interested in three dimensions that are likely to affect innovation, namely trade policy, competition policy, and international agreements. First, to measure trade policy, we include tariffs[12] and non-tariff measures (measured by the non-tariff trade costs with the main trading partner). As per international agreements, the impact of IPRs agreements is addressed by adding WIPO membership and TRIPS agreement as explanatory variables[13] to the baseline specification. Finally, the effectiveness of the anti-monopoly law index is added to address the impact of competition policy on domestic innovation.

To untangle the heterogeneous effect of GVC knowledge spillovers in accordance with income groups, fixed effects regressions presented in equation 2 are repeated while interacting the variable of interest with the four income groups relying on the World Bank classification definition. Due to the expected endogeneity of GVC[14], we adopt an instrumental variables approach. Finally, to further ensure results' robustness, GVCRD and resident patent per capita are alternated with a

[11] Number of researchers working in R&D per million of the population.
[12] Applied weighted mean tariff rate on manufactured products.
[13] Both are dummy variables equal to 1 if the country is a member of the WIPO/signed an agreement involving TRIPS and 0 otherwise.
[14]The relationship between GVC and innovation is endogenous and mutually affecting (Pietrobelli and Rabellotti, 2011).

backward participation GVC index from the TiVA dataset and non-resident patent per capita consecutively.

Based on patents' data availability, our sample consists of 83 countries from the year 1990 until 2019. Data relies on the World Development indicators (WDI) dataset to measure the resident and non- resident patent[15] per capita. R&D stock is the number of researches working in R&D per million of the population relying on the WDI dataset. Similarly, GDP per capita (constant 2010 US$), tariffs on manufactured products, as well as oil exports as a percentage of merchandise exports rely on the WDI. Time to enforce contracts comes from the Doing Business dataset whereas rule of law relies on the World Bank World Governance Indicators dataset. WTO membership relies on WTO data. WIPO membership relies on WIPO dataset. TRIPS agreement relies on the World Bank Deep Trade Agreements dataset. Non-tariff measures are proxied by the comprehensive non-tariff indicator relying on the ESCAP-World Bank trade costs dataset. Competition is measured by the effectiveness of the anti-monopoly index relying on the Global Competitiveness Index of the World Economic Forum dataset. The alternative backward participation GVC index is the share of foreign value added exported in total value-added exported relying on TiVA dataset for a sample of 57 countries from the year 1995 until 2018.

5. Empirical Results

Results of the effect of GVC knowledge spillovers (GVCRD) on resident patent per capita are reported in tables 1 to 7. We present the baseline results in table 1 by gradually including explanatory variables in columns 1 to 6 . Column (1) shows the main control variables having the expected signs. Domestic R&D stock exerts a positive and significant effect on resident patent per capita being the former the main innovation input. Likewise, both income level and population exert a positive effect on resident patent per capita while tariffs and oil exports exert a negative effect. Indeed, trade barriers limit knowledge driven globalization whereas oil dependence challenges innovation due to the high concentration in low value-added extracting activities. Column (2) shows the negative and significant interaction between domestic R&D stock and GVCRD. As domestic R&D stock increases, the impact of GVCRD on resident patent per capita decreases due to the substitution effect. Indeed, in light of globalization, both domestic and foreign R&D are substitutable inputs to domestic innovation (Coe and Helpman, 1995). Column (3) shows that the effect of time to enforce contracts on domestic innovation is insignificant. Columns (4) and (5) synthesize the heterogeneous effect of WTO membership in varying income levels by interacting WTO membership with the sample of countries excluding low-income. As shown in column (6), all the main control variables are significant and preserve their signs. Rule of law exerts a positive and significant effect on resident patent per capita. The positive and significant WTO membership excluding low-income countries and its opposing negative effect as low-income countries are included reveal an unintended bias of WTO membership against the latter. Results line up with the argument that WTO international standards generate adverse welfare effects in low-income countries (Jansen, 2010; Zelicovich, 2021) and provide evidence on the synthesis suggesting that enhanced IPRs imposed on WTO member countries transfers welfare from less developed (importers of technology) to higher developed (exporters of technology) countries (Helpman, 1993; McCalman, 2002) due to the increased cost of imitation. Yet, to further validate this conclusion, we integrate IPRs agreements in the regression.

[15] Number of applications for process, design, and product.

Table 1 Baseline regression for the effect of GVCRD on resident patent per capita

	Dependent Variable: Log of Resident Patent per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
GVCRD	.126	2.004***	1.981***	2.198***	2.075***	2.08***
	(.088)	(.2)	(.201)	(.207)	(.206)	(.206)
RD Stock	.05**	.141***	.139***	.164***	.151***	.157***
	(.022)	(.024)	(.024)	(.024)	(.024)	(.024)
GDP per capita	.298***	.252***	.265***	.341***	.344***	.251***
	(.063)	(.062)	(.063)	(.066)	(.065)	(.068)
Population	.243	.243	.242	.303**	.501***	.624***
	(.154)	(.15)	(.15)	(.15)	(.152)	(.154)
Tariffs	-.012***	-.011***	-.011***	-.011***	-.01***	-.01***
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
Fuel Exports	-.003***	-.003***	-.003***	-.003***	-.003***	-.003***
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
RD*GVCRD		-.482***	-.479***	-.515***	-.482***	-.482***
		(.046)	(.046)	(.047)	(.047)	(.047)
Time to Contracts			-.143	-.112	-.13	-.09
			(.133)	(.133)	(.132)	(.132)
WTO				-.074***	-.521***	-.509***
				(.018)	(.07)	(.07)
WTO*low-excluded					.469***	.454***
					(.071)	(.071)
Rule of Law						.004***
						(.001)
Constant	-7.818***	-9.51***	-9.134***	-10.212***	-11.448***	-12.366***
	(1.061)	(1.051)	(1.108)	(1.136)	(1.141)	(1.155)
No. of Observations	2490	2490	2490	2490	2490	2490
No. of Countries	83	83	83	83	83	83
R^2	.135	.173	.173	.179	.193	.2
Country FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors are in parentheses. Fixed effects are removed for brevity. *** $p<.01$, ** $p<.05$, * $p<.1$

R&D stock, GDP per capita, population, and time to enforce contracts are expressed in logarithm.

We present the results of IPRs namely TRIPS trade agreement and WIPO membership in table 2 to examine the adverse welfare effect on low-income countries signaled in WTO membership results. Although property rights' protection incentivizes inventors, the former increases the cost of imitation on disadvantaged laggards. From a different lens, IPRs play a vital role in sustaining the competitive advantage of high value added intangible[16] capital constituting more than 30% of total GVC capital on average (WIPO, 2017). Again, this advantage singles out advantaged developed economies leaving developing ones at higher catch-up costs. Consistent with WTO membership results, column (3) shows that TRIPS interaction with all countries excluding low-income is positive and significant opposite to its negative effect for all countries. Heterogeneously, column (4) shows that WIPO exerts a positive and significant effect on resident patent per capita and column (5) shows vanishing significance as the former is interacted with all countries excluding low-income. Despite the insignificant interaction of TRIPS and GVCRD shown in column (7), columns (8) and (9) show that WIPO is negatively and significantly interacted with both the former and the latter. Although both IPRs agreements aim at incentivizing innovation, TRIPS is more effective for two reasons. First, TRIPS is a binding agreement while WIPO specifies non-binding mediation in resolving disputes. Second, TRIPS provide flexibility of regulations to governments unlike WIPO standardizing a one size fits all regulations' system (McCalman, 2005).

[16] Refers to brand, design, science and technology.

Table 2 The effect of IPRs agreements on resident patent per capita

	Dependent Variable: Log of Resident Patent per capita							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GVCRD	2.08***	2.106***	2.118***	2.104***	2.104***	2.106***	2.05***	2.092***
	(.206)	(.206)	(.205)	(.205)	(.206)	(.207)	(.206)	(.206)
RD Stock	.157***	.164***	.169***	.165***	.165***	.165***	.155***	.161***
	(.024)	(.024)	(.024)	(.024)	(.024)	(.024)	(.024)	(.024)
GDP per capita	.251***	.294***	.287***	.281***	.281***	.28***	.267***	.262***
	(.068)	(.071)	(.071)	(.071)	(.071)	(.071)	(.071)	(.071)
Population	.624***	.648***	.697***	.564***	.564***	.564***	.57***	.561***
	(.154)	(.154)	(.155)	(.161)	(.161)	(.161)	(.161)	(.16)
Tariffs	-.01***	-.01***	-.01***	-.01***	-.01***	-.01***	-.01***	-.01***
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
Fuel Exports	-.003***	-.003***	-.004***	-.004***	-.004***	-.004***	-.004***	-.004***
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
RD*GVCRD	-.482***	-.485***	-.484***	-.481***	-.48***	-.482***	-.435***	-.438***
	(.047)	(.047)	(.047)	(.047)	(.047)	(.048)	(.048)	(.049)
Time to Contracts	-.09	-.098	-.074	-.051	-.051	-.051	-.052	-.094
	(.132)	(.132)	(.132)	(.132)	(.132)	(.132)	(.132)	(.132)
WTO	-.509***	-.511***	-.459***	-.444***	-.444***	-.445***	-.428***	-.434***
	(.07)	(.07)	(.072)	(.072)	(.072)	(.072)	(.072)	(.072)
WTO*low-excluded	.454***	.466***	.406***	.388***	.388***	.388***	.373***	.384***
	(.071)	(.071)	(.073)	(.074)	(.074)	(.074)	(.074)	(.074)
Rule of Law	.004***	.004***	.004***	.004***	.004***	.004***	.004***	.004***
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
TRIPS		-.04**	-.249***	-.251***	-.251***	-.256***	-.28***	-.192**
		(.019)	(.071)	(.07)	(.075)	(.083)	(.075)	(.094)
TRIPS*low-excluded			.224***	.214***	.215***	.215***	.256***	.234***
			(.073)	(.073)	(.077)	(.078)	(.078)	(.079)
WIPO				.066***	.068	.07	.156	.193*
				(.023)	(.1)	(.101)	(.102)	(.105)
WIPO*low-excluded					-.002	-.005	.079	.088
					(.102)	(.104)	(.104)	(.105)
TRIPS*GVCRD						.007		.062
						(.054)		(.056)
WIPO*GVCRD							-.246***	-.275***
							(.068)	(.072)
WIPO*TRIPS								-.13***
								(.038)
Constant	-12.366***	-12.725***	-13.124***	-12.206***	-12.206***	-12.207***	-12.101***	-11.997***
	(1.155)	(1.167)	(1.172)	(1.212)	(1.212)	(1.212)	(1.209)	(1.207)
No. of Observations	2490	2490	2490	2490	2490	2490	2490	2490
No. of Countries	83	83	83	83	83	83	83	83
R^2	.2	.201	.205	.207	.207	.207	.212	.216
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors are in parentheses. Fixed effects are removed for brevity. ****p<.01, **p<.05, *p<.1*
R&D stock, GDP per capita, population, and time to enforce contracts are expressed in logarithm.

Relevant to the significant negative tariffs' effect on domestic innovation presented in baseline results, we are interested in exploring the effect of non-tariff measures (NTMs) to know the extent of relevance of trade policy to innovation and GVC. Table 3 presents the results of integrating NTMs in our regression framework. Consistent with tariffs' estimate in column (1), column (2) shows that NTMs exert a negative and a significant effect on resident patent per capita. Sensibly, time to enforce contracts shows a negative and significant effect as NTMs are controlled for. Indeed, NTMs originate from domestic regulations including certification, licensing, and contractual procedures. Likewise, as NTMs increase, the positive effect of GVCRD on domestic innovation decreases evidenced in the negative and significant interaction of NTMs and GVCRD in column (3). Indeed, trade barriers constrain GVC integration and hence decreases the latter's knowledge spillovers effect. From another angle, trade agreements can moderate trade barriers due to the well-defined binding rules and regulations among partners. Hence, although columns (4) and (5) show an insignificant effect of TRIPS on resident patent per capita, column (6) shows a negative and significant interaction between TRIPS and NTMs. When combined with TRIPS positive direct effect, the interaction indicates a dampened effect as NTMs increase. Similarly, while columns (7) to (9) show that WIPO exert an insignificant effect on resident patent per capita, the former is negatively and significantly interacted with both tariffs and NTMs.

Similar to IPRs, competition gains single out economies with higher capacities and therefore easier catch up. Results of integrating the effectiveness of anti-monopoly law index as a *de jure* measure of competition to the baseline specification are presented in table 4. Column (3) shows an inverted U-shaped relationship between competition and resident patent per capita. Indeed, the effect of competition on domestic innovation is complex, non-linear, and unexpectedly changes (Aghion et al., 2005). From a theoretical standpoint, as the *de jure* competition index increases, inventors (leaders) expect new entrants and hence engage in patenting to protect their inventions. Yet, increased market entry and patents due to enhanced competition is unguaranteed for two reasons. First, entry of followers is endogenous to firms' capabilities and absorptive capacities (Corrado et al., 2013). Second, alternative to patenting, leaders can choose to engage in trade secrets to protect their monopoly power (Crass et al., 2019). Column (4) shows that the competition index is negatively and significantly interacted with GVCRD. As the effectiveness of anti-monopoly law increases, the GVC knowledge spillovers effect decreases. Indeed, developed economies -rich in human and physical capital- have less knowledge spillovers effect than counterparts with less absorptive capacities. Columns (6) and (8) show the positive and significant interaction between competition and IPRs. While results show that both variables are complementary in incentivizing innovation, positive gains are directed towards developed leader economies. Consistent estimates are shown in column (9) as all the variables are included in one regression.

Table 5 presents the results of GVCRD interaction with income groups to disentangle the GVC knowledge spillovers effect in correspondence with varying income levels. Column (1) shows the results of baseline regression for comparison. Column (2) provides evidence on two main theoretical foundations. First, the backwardness effect (Aghion and Howitt, 2007) is shown in the interaction between GVCRD and lower middle-income group. In reference to high-income, lower middle-income countries have the highest positive effect of knowledge spillovers. Indeed, countries at earlier stages of development benefit more from knowledge spillovers than developed ones. Second, knowledge spillovers require a threshold of minimum absorptive capacity (Falvey et al., 2007). As shown in the insignificant interaction between low-income countries and GVCRD,

Table 3 The effect of trade policy on resident patent per capita

	Dependent Variable: Log of Resident Patent per capita								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
GVCRD	2.08***	1.691***	2.651***	2.639***	2.625***	2.545***	2.599***	2.565***	2.565***
	(.206)	(.207)	(.338)	(.342)	(.342)	(.339)	(.341)	(.342)	(.342)
RD Stock	.157***	.122***	.117***	.117***	.121***	.106***	.118***	.109***	.109***
	(.024)	(.024)	(.024)	(.024)	(.024)	(.024)	(.024)	(.024)	(.024)
GDP per capita	.251***	.055	.104	.11	.11	.011	.106	.108	.108
	(.068)	(.075)	(.076)	(.08)	(.08)	(.081)	(.076)	(.076)	(.076)
Population	.624***	.704***	.614***	.621***	.623***	.874***	.663***	.701***	.701***
	(.154)	(.173)	(.174)	(.176)	(.176)	(.178)	(.18)	(.181)	(.181)
Tariffs	-.01***	-.016***	-.017***	-.017***	-.017***	-.017***	-.017***	-.017***	-.017***
	(.001)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
Fuel Exports	-.003***	-.003***	-.003***	-.003***	-.003***	-.003***	-.003***	-.003***	-.003***
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
RD*GVCRD	-.482***	-.408***	-.453***	-.452***	-.449***	-.425***	-.448***	-.447***	-.447***
	(.047)	(.047)	(.048)	(.048)	(.048)	(.048)	(.048)	(.048)	(.048)
Time to Contracts	-.09	-.292**	-.313***	-.313***	-.305***	-.421***	-.324***	-.334***	-.334***
	(.132)	(.118)	(.118)	(.118)	(.118)	(.118)	(.119)	(.119)	(.119)
WTO	-.509***	-.951***	-.946***	-.948***	-.949***	-.987***	-.952***	-.943***	-.943***
	(.07)	(.088)	(.088)	(.088)	(.088)	(.088)	(.088)	(.088)	(.088)
WTO*low-excluded	.454***	1.031***	1.039***	1.041***	1.043***	1.087***	1.044***	1.036***	1.036***
	(.071)	(.092)	(.092)	(.092)	(.092)	(.092)	(.092)	(.092)	(.092)
Rule of Law	.004***	.003***	.003***	.003***	.003***	.003***	.003***	.003***	.003***
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
NTMs		-.002***	-.002***	-.002***	-.002***	-.003586	-.002***	-.001	-.001
		(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
NTMs*GVCRD			-.011***	-.011***	-.011***	-.01***	-.01***	-.01***	-.01***
			(.003)	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)
TRIPS				-.005	-.03	.296***			
				(.022)	(.027)	(.05)			
TRIPS* Tariffs					.004				
					(.003)				
TRIPS*NTMs						-.004***			
						(.001)			
WIPO							-.026	.105	-.009
							(.025)	(.074)	(.027)
WIPO*Tariffs								-.002*	
								(.001)	
WIPO*NTMs									-.002*
									(.001)
Constant	-12.366***	-10.993***	-11.044***	-11.103***	-11.17***	-12.304***	-11.329***	-11.592***	-11.592***
	(1.155)	(1.261)	(1.257)	(1.284)	(1.285)	(1.283)	(1.286)	(1.293)	(1.293)
No. of Observations	2490	2050	2050	2050	2050	2050	2050	2050	2050
No. of Countries	83	82	82	82	82	82	82	82	82
R^2	.2	.23	.235	.235	.236	.252	.236	.237	.237
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors are in parentheses. Fixed effects are removed for brevity. *** *p<.01, ** p<.05, * p<.1*

R&D stock, GDP per capita, population, and time to enforce contracts are expressed in logarithm, NTMs are total trade costs with the main trade partner excluding tariffs.

Table 4 The effect of competition policy on resident patent per capita

	Dependent Variable: Log of Resident Patent per capita								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
GVCRD	2.08***	1.699***	1.635***	1.975***	1.963***	1.834***	1.995***	1.964***	1.863***
	(.206)	(.213)	(.212)	(.267)	(.267)	(.268)	(.267)	(.266)	(.267)
RD Stock	.157***	.129***	.123***	.116***	.116***	.11***	.119***	.114***	.11***
	(.024)	(.025)	(.025)	(.025)	(.025)	(.025)	(.025)	(.025)	(.025)
GDP per capita	.251***	.087	.19**	.185**	.232***	.268***	.196**	.172**	.238***
	(.068)	(.078)	(.079)	(.079)	(.084)	(.085)	(.079)	(.079)	(.085)
Population	.624***	.672***	.88***	.95***	.989***	.95***	1.059***	1.103***	1.078***
	(.154)	(.177)	(.18)	(.183)	(.184)	(.183)	(.188)	(.188)	(.188)
Tariffs	-.01***	-.016***	-.015***	-.015***	-.016***	-.015***	-.016***	-.016***	-.016***
	(.001)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
Fuel Exports	-.003***	-.003***	-.003***	-.003***	-.003***	-.003***	-.003***	-.003***	-.003***
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
RD*GVCRD	-.482***	-.394***	-.364***	-.35***	-.35***	-.322***	-.343***	-.353***	-.332***
	(.047)	(.048)	(.048)	(.048)	(.048)	(.048)	(.048)	(.048)	(.048)
Time to Contracts	-.09	-.224*	-.125	-.084	-.092	-.098	-.102	-.126	-.129
	(.132)	(.12)	(.12)	(.122)	(.122)	(.122)	(.122)	(.122)	(.121)
WTO	-.509***	-1.004***	-1.024***	-1.014***	-1.028***	-1.022***	-1.027***	-1.043***	-1.045***
	(.07)	(.088)	(.088)	(.088)	(.088)	(.088)	(.088)	(.088)	(.088)
WTO*low-excluded	.454***	1.083***	1.094***	1.089***	1.103***	1.114***	1.101***	1.122***	1.135***
	(.071)	(.092)	(.092)	(.092)	(.092)	(.092)	(.092)	(.091)	(.092)
Rule of Law	.004***	.003***	.003***	.003***	.003***	.002***	.003***	.003***	.002***
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
Anti-Monopoly		.001	.868***	.822***	.837***	.627***	.852***	.591***	.493***
		(.016)	(.161)	(.163)	(.163)	(.169)	(.163)	(.171)	(.174)
(Anti-Monopoly)^2			-3.502***	-3.084***	-3.148***	-2.48***	-3.167***	-2.587***	-2.243***
			(.648)	(.678)	(.679)	(.693)	(.678)	(.686)	(.696)
Anti-Monopoly*GVCRD				-.106**	-.103**	-.099*	-.117**	-.088*	-.086*
				(.051)	(.051)	(.051)	(.051)	(.051)	(.051)
TRIPS					-.034	-.379***			-.28***
					(.021)	(.082)			(.086)
TRIPS*Anti-Monopoly						.083***			.06***
						(.019)			(.02)
WIPO							-.058**	-.57***	-.464***
							(.025)	(.112)	(.117)
WIPO*Anti-Monopoly								.128***	.104***
								(.027)	(.028)
Constant	-12.366***	-11.261***	-9.852***	-11***	-11.355***	-11.576***	-11.687***	-11.975***	-12.242***
	(1.155)	(1.278)	(1.295)	(1.407)	(1.424)	(1.418)	(1.437)	(1.431)	(1.437)
No. of Observations	2490	2075	2075	2075	2075	2075	2075	2075	2075
No. of Countries	83	83	83	83	83	83	83	83	83
R^2	.2	.217	.229	.231	.232	.239	.233	.241	.245
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors are in parentheses. Fixed effects are removed for brevity. *** $p<.01$, ** $p<.05$, * $p<.1$

R&D stock, GDP per capita, population, and time to enforce contracts are expressed in logarithm. Anti-Monopoly is effectiveness of the anti-monopoly law index.

the spillover effect is constrained by the lesser absorptive capacity. As previously mentioned, low-income countries have the least R&D stock signaling the extent of low human and physical capital accumulation.

Table 5 The effect of GVCs on innovation in different income groups

	Dependent Variable: Log of Resident Patent per capita	
	(1)	(2)
GVCRD	2.08***	1.684***
	(.206)	(.331)
GVCRD*UpperMiddle		-.006
		(.216)
GVCRD*LowerMiddle		.681***
		(.228)
GVCRD*LowIncome		-.364
		(1.179)
RD Stock	.157***	.123***
	(.024)	(.026)
GDP per capita	.251***	.3***
	(.068)	(.069)
Population	.624***	.603***
	(.154)	(.156)
Tariffs	-.01***	-.01***
	(.001)	(.001)
Fuel Exports	-.003***	-.004***
	(.001)	(.001)
RD*GVCRD	-.482***	-.453***
	(.047)	(.052)
Time to Contracts	-.09	-.071
	(.132)	(.133)
WTO	-.509***	-.503***
	(.07)	(.07)
WTO*low-excluded	.454***	.458***
	(.071)	(.071)
Rule of Law	.004***	.004***
	(.001)	(.001)
Constant	-12.366***	-12.053***
	(1.155)	(1.182)
No. of Observations	2490	2490
No. of Countries	83	83
R^2	.2	.206
Country FE	Yes	Yes

Notes: Standard errors are in parentheses. Fixed effects are removed for brevity. *** *p*<.01, ** *p*<.05, * *p*<.1
R&D stock, GDP per capita, population, and time to enforce contracts are expressed in logarithm

Table 6 presents three robustness checks to the baseline regression results. Again, column (1) presents the baseline results for comparison. Column (2) shows the results of the instrumental variables approach. The instruments used are the log of GDP per capita and rule of law of the main trading partner. The rationale is that both instruments strengthen GVC knowledge spillovers to destination countries and both are exogenous to resident patents in the latter. As GDP per capita in origin country increases (decreases), GVC knowledge spillovers to destination increases (decreases) due to the accompanied higher (lower) foreign R&D. Likewise, rule of law determines the degree of GVC governance in origin countries which goes hand in hand with the volume of exported intermediaries (Gereffi et al., 2005) and hence enhances knowledge spillovers to destinations. Indeed, results show robustness as the variable of interest exerts the same significant and positive effect when instrumental variables are employed. Most of the control variables

preserve the same significance and signs as the baseline results. Column (3) shows the results when an alternative backward GVC index[17] from TiVA dataset is used. In this regression, R&D expenditure as a percentage of GDP is used instead of R&D stock. As presented, the GVC index as well as all the explanatory variables preserve the same significance and signs as baseline results. Finally, column (4) presents the results when the dependent variable is altered with a substitute of resident patent per capita. Expectedly, the effect of the variable of interest is inverted with preserved significance showing that an increase in GVCRD results in an increase in resident patent per capita mirrored in a decline in non- resident patent per capita. Similarly, as domestic R&D stock increases, innovators shift from non-resident licenses to resident ones.

Table 6 Robustness checks

Dependent Variable:	log of Resident patent per capita			log of non-resident patent per capita
	Baseline	IV	TiVA	
	(1)	(2)	(3)	(4)
GVCRD/GVC	2.08***	2.433***	.036***	-1.238*
	(.206)	(.433)	(.005)	(.674)
RD Stock/exp	.157***	.367***	.949***	-.664***
	(.024)	(.063)	(.104)	(.079)
GDP per capita	.251***	-.079	.394***	-.616***
	(.068)	(.101)	(.087)	(.224)
Population	.624***	.544***	1.344***	2.947***
	(.154)	(.178)	(.179)	(.506)
Tariffs	-.01***	-.009***	-.021***	-.028***
	(.001)	(.001)	(.005)	(.004)
Fuel Exports	-.003***	-.002*	-.008***	0
	(.001)	(.001)	(.002)	(.003)
RD*GVCRD	-.482***		-.025***	-.272*
	(.047)		(.003)	(.153)
Time to Contracts	-.09	.256	-.196	-1.305***
	(.132)	(.172)	(.119)	(.432)
WTO	-.509***	-.667***	.17**	.266
	(.07)	(.083)	(.074)	(.229)
WTO*low-excluded	.454***	.554***		-.264
	(.071)	(.081)		(.232)
Rule of Law	.004***	.004***	.012***	.005
	(.001)	(.001)	(.003)	(.003)
Constant	-12.366***	-12.901***	-37.208***	-20.628***
	(1.155)	(1.399)	(3.074)	(3.791)
No. of Observations	2490	2490	1368	2490
No. of Countries	83	83	57	83
R^2	.2	.03	.369	.092
Country FE	Yes	Yes	Yes	Yes

Notes: Standard errors are in parentheses. Fixed effects are removed for brevity. *** $p<.01$, ** $p<.05$, * $p<.1$ R&D stock, GDP per capita, population, and time to enforce contracts are expressed in logarithm. Instrumental variables: log of partner's GDP per capita and partner's rule of law. Variable of interest in TiVA dataset is the backwardness participation index.

We present the results of all explanatory variables against different datasets in table 7. Column (1) presents the results using EORA26 dataset. As shown, both the significance and the signs of all variables are preserved. Column (2) shows homogenous results using TiVA dataset. Notably, TiVA dataset excludes low-income countries clarifying the vanished bias of both WTO

[17] This is a more complex definition of GVC since it is a measure of the share of foreign value added that is exported whereas the simple definition is limited to the share of foreign value added absorbed.

membership and TRIPS. Alternatively, unlike TRIPS, WIPO exerts a negative and significant effect on resident patent per capita. Likewise, NTMs is insignificant in TiVA dataset while competition maintains the same inverted U-shaped relationship.

Table 7 All explanatory variables against datasets

	Dependent Variable: Log of Resident Patent per capita	
	EORA26	TiVA
	(1)	(2)
GVCRD/GVC	1.66***	.041***
	(.209)	(.005)
RD Stock/exp	.13***	1***
	(.025)	(.102)
GDP per capita	.178**	.234**
	(.083)	(.095)
Population	1.124***	1.677***
	(.183)	(.192)
Tariffs	-.014***	-.019***
	(.002)	(.005)
Fuel Exports	-.004***	-.007***
	(.001)	(.002)
RD*GVC	-.374***	-.025***
	(.047)	(.003)
Time to Contracts	-.175	-.114
	(.119)	(.12)
WTO	-.984***	.169**
	(.087)	(.075)
WTO*low-excluded	1.046***	
	(.091)	
Rule of Law	.002*	.012***
	(.001)	(.003)
TRIPS	-.325***	.227***
	(.071)	(.052)
TRIPS*low-excluded	.339***	
	(.074)	
WIPO	-.054	-.187***
	(.116)	(.057)
WIPO*low-excluded	-.001	
	(.12)	
NTMs	-.002***	-.002
	(.001)	(.002)
Anti-Monopoly	1.007***	2.582***
	(.16)	(.528)
(Anti-Monopoly)^2	-4.027***	-10.089***
	(.64)	(2.272)
Constant	-10.774***	-32.204***
	(1.32)	(3.909)
No. of Observations	2050	1368
No. of Countries	82	57
R^2	.256	.405
Country FE	Yes	Yes

Notes: Standard errors are in parentheses. Fixed effects are removed for brevity. *** *p<.01,* ** *p<.05,* * *p<.1* R&D stock, GDP per capita, population, and time to enforce contracts are expressed in logarithm. NTMs are total trade costs with the main trade partner excluding tariffs. Anti-Monopoly is the effectiveness of the anti-monopoly law index.

In summary, empirical results show that backward participation linkages to GVC exert a positive and significant effect on resident patent per capita particularly in lower-middle income group. Yet, trade policy, IPRs agreements and competition policy interferes in this effect. Moreover, our

results remain robust when an instrumental variables approach is employed and when alternative variables to the variables of interest are used. Grounded on the presented empirical results, we argue the following: First, GVC participation is accompanied by knowledge spillovers to destination countries. Second, the quality of institutions matters to domestic innovation reflected in the persistent positive and significant effect of rule of law. Third, TRIPS agreement is effective in incentivizing innovation unlike WIPO that exerts an opposing trajectory. Fourth, both tariffs and NTMs matter for innovation and the latter reduces the positive GVC knowledge spillovers. Fifth, although competition has a positive impact on domestic innovation and interacts positively with IPRs agreements, the former exerts a non-monotonic inverted U-shaped relationship on resident patent per capita.

6. Conclusion

By emphasizing the relevance of GVC participation as a channel for fostering domestic innovation, we draw several conclusions. We show that the constructed GVC knowledge spillovers index exerts a positive and significant effect on resident patent per capita. We also analyze how the quality of institutions, IPRs agreements, trade policy and competition policy matter for the effect of GVC participation on innovation. In particular, we show that rule of law, TRIPS, and competition exert a direct positive effect on innovation. Whereas tariffs and NTMs exert a direct negative effect and the latter dampens the positive effect of GVC knowledge spillovers. Yet, our results imply an unintended bias of both WTO membership and TRIPS agreement against low-income countries. We also conclude that the positive effect of enhanced competition is indeterministic due to the captured inverted U-shaped relationship. Moreover, we provide considerable implications to developing countries. On the one hand, disentangling the effect of GVC knowledge spillovers in accordance with different income groups highlights the former's particular importance to lower-middle income countries disadvantaged in technology production. Nevertheless, results for low-income countries with limited absorptive capacity show an insignificant impact. On the other hand, we highlight that GVC knowledge spillovers are challenged by high NTMs, weak institutions, as well as lax competition policy prevalent in developing countries.

This study contributes to the post COVID-19 controversial discourse on the trade-off of reshoring activities by evidencing the opportunity cost of decoupling in terms of domestic innovation. Empirical results suggest an externality learning effect of GVC participation provided an unyielding convalescence of mitigating preconditions. From a policy standpoint, the positive and significant effect of GVC on innovation advocates encouraging backward linkages to GVC particularly in lower-middle income countries exhibiting the highest positive effect of GVC knowledge spillovers. To this end, recommended policies to fostering the learning effect of GVC participation in developing countries are fivefold. First, lowering unnecessary trade costs is key to encouraging foreign exporters of intermediate goods. Second, policies targeting institutions' evolution and rule of law promotion are compulsory to fostering the foreign learning effect of GVC participation. Third, negotiations of deep trade agreements involving property rights are central to guarantying unbiases against low-income countries disadvantaged in technology production. Fourth, enhancing competition in countries with lax competition policy incentivizes innovation and complements the positive impact of IPRs agreements on domestic innovation. Yet, enforcing competition should be implemented with caution due to the non-linearity of the effect.

Fifth, fostering the absorptive capacity in low-income countries by investing in human and physical capital is necessary to realizing GVC knowledge spillovers. Moreover, the evidence-based policies provided by this paper paves to the ninth global goal[18] of the United Nations sustainable development goals (SDGs) intended to be achieved by the year 2030.

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[18] SDG 9 aims at building resilient infrastructure, promoting industrialization, and fostering innovation.

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Appendix

Table A1 Dataset countries and income groups classification

	Country	Income Group		Country	Income Group
1	Algeria	Upper Middle	**43**	Lithuania	High
2	Argentina	Upper Middle	**44**	Luxembourg	High
3	Armenia	Upper Middle	**45**	Madagascar	Low
4	Australia	High	**46**	Malta	High
5	Austria	High	**47**	Malaysia	Upper Middle
6	Bangladesh	Lower Middle	**48**	Mexico	Upper Middle
7	Belarus	Upper Middle	**49**	Moldova	Lower Middle
8	Belgium	High	**50**	Monaco	High
9	Brazil	Upper Middle	**51**	Mongolia	Low
10	Bulgaria	Upper Middle	**52**	Morocco	Lower Middle
11	Canada	High	**53**	Netherlands	High
12	Chile	High	**54**	New Zealand	High
13	China	Upper Middle	**55**	Norway	High
14	Colombia	Upper Middle	**56**	Pakistan	Lower Middle
15	Costa Rica	Upper Middle	**57**	Peru	Upper Middle
16	Croatia	High	**58**	Philippines	Lower Middle
17	Cuba	Upper Middle	**59**	Poland	High
18	Czech Republic	High	**60**	Portugal	High
19	Denmark	High	**61**	Romania	Upper Middle
20	Ecuador	Upper Middle	**62**	Russian Federation	Upper Middle
21	Egypt	Lower Middle	**63**	Saudi Arabia	High
22	Finland	High	**64**	Singapore	High
23	France	High	**65**	Slovak Republic	High
24	Georgia	Upper Middle	**66**	South Africa	Upper Middle
25	Germany	High	**67**	Spain	High
26	Greece	High	**68**	Sri Lanka	Upper Middle
27	Guatemala	Upper Middle	**69**	Sweden	High
28	Hong Kong	High	**70**	Switzerland	High
29	Hungary	High	**71**	Syria	Low
30	Iceland	High	**72**	Tajikistan	Low
31	India	Lower Middle	**73**	Thailand	Upper Middle
32	Indonesia	Lower Middle	**74**	Tunisia	Lower Middle
33	Iran	High	**75**	Turkey	Upper Middle
34	Israel	High	**76**	Ukraine	Lower Middle
35	Italy	High	**77**	United Kingdom	High
36	Jamaica	Upper Middle	**78**	United States	High
37	Japan	High	**79**	Uruguay	High
38	Kazakhstan	Upper Middle	**80**	Uzbekistan	Lower Middle
39	Kenya	Lower Middle	**81**	Venezuela	Upper Middle
40	Korea	High	**82**	Vietnam	Lower Middle
41	Kyrgyz Republic	Lower Middle	**83**	Zambia	Lower Middle
42	Latvia	High			

Table A2 EORA26 sectors

1	Agriculture
2	Fishing
3	Mining and Quarrying
4	Food & Beverages
5	Textiles and Wearing Apparel
6	Wood and Paper
7	Petroleum, Chemical and Non-Metallic Mineral Products
8	Metal Products
9	Electrical and Machinery
10	Transport Equipment
11	Other Manufacturing
12	Recycling
13	Electricity, Gas and Water
14	Construction
15	Maintenance and Repair
16	Wholesale Trade
17	Retail Trade
18	Hotels and Restaurants
19	Transport
20	Post and Telecommunications
21	Financial Intermediation and Business Activities
22	Public Administration
23	Education, Health and Other Services
24	Private Households
25	Others
26	Re-export & Re-import