On GVC and Innovation: Does the Quality of Institutions Matter?

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Abstract

This paper investigates the relationship between global value chains (GVC) participation and countries' innovation performance. Indeed, importing intermediate goods creates knowledge spillovers across countries along the chain. Exploring the learning effect through GVC participation contributes to the controversial query in literature regarding the biasness of GVC participation against developing countries with abundant unskilled labor. We merge the EORA26 dataset with the World Development Indicators' R&D stock data to construct the weighted foreign knowledge spillovers backward participation index. We show a significant association between the constructed GVC index and innovation measured by residents' patent per capita in lower middle and low-income countries. In addition, we show the significance of the interaction between domestic R&D and foreign R&D weighted offshoring on residents' patent per capita. Furthermore, we show that the business environment matters for domestic innovation. Results show a negative and significant effect of enforcing contracts' time on residents' patent per capita. We also tackle the endogeneity of GVC by using a two-stage instrumental variable regression to ensure results' robustness. Finally, based on empirical results, this paper offers policy implications to lower middle and low-income countries to the end of enhancing domestic innovation.

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1. Introduction

In the recent three decades, the number of countries participating in Global Value Chains (GVC) as well as the value of traded intermediate goods have been increasing. However, this trend is altered in the preceding years. The wave of "slowbalization" is augmented with the COVID-19 pandemic crisis to unbind the interdependence between industries and countries aiming at preventing the domino effect stirring in crises. Despite the recent recommendations of "reshoring" activities, the benefits of outsourcing at the country level should not be overlooked. Indeed, the positive gains of GVC participation are addressed as early as the emergence of the New Trade Theory emphasizing the paradigm shifts to increasing returns to scale, imperfect competition, and intra industry trade (Krugman, 1980; Helpman and Krugman, 1985). Accordingly, the phenomenal uprising scale of GVC participation since the early 1990s is rationalized by "unbundling" and decreased communication costs in light of the fourth industrial revolution (Feenstra and Hanson, 1996; Grossman and Rossi-Hansberg, 2008; Baldwin, 2013).

The impact of trade in value added is not limited to terms of trade. Similar to the reviewed nexus between trade in final goods and services and innovation (Alessandria et al., 2021; Ackigit and Melitz, 2021), GVC participation is ordinary to have a knowledge driven effect on innovation. Indeed, backward participation linkages to GVC transfer knowledge that can be signaled by countries' innovation performance over time. According to the conceptual innovation framework, R&D personnel and R&D expenditures are the inputs to innovation, whereas patenting is the indicator of knowledge creation (Raghupathi and Raghupathi, 2019). Undeniably, the gains of international product fragmentation in terms of technological spillovers are still subject to empirical exploration. This paper aims at highlighting the nexus between GVC participation and innovation through foreign weighted knowledge spillovers. This study emphasizes the potential prospect for developing countries in realizing innovation driven economic growth. Indeed, the share of innovation driven growth accounts to more than 50% of the economic growth drivers[2] (OECD, 2005; Kayal, 2008).

Using the simple[3] offshoring definition, this paper aims at synthesizing the gains of GVC participation in terms of innovation by empirically estimating the impact of foreign knowledge weighted GVC on residents' patent per capita. In addition, the effect of the business environment on innovation is estimated to unveil the conceivable mitigating effect of a humble business environment. Based on theoretical and empirical literature suggesting a robust association between contracting time and patenting, we use the time to enforce contracts as a business environment indicator. Furthermore, the understudied income groups are singled out in the econometric baseline regression to untangle the heterogeneous learning impact of foreign knowledge spillovers in accordance with varying income levels.

This paper is composed of five sections structured as follows: Section 2 presents a review of literature on GVC and innovation. Section 3 presents stylized facts and descriptive analysis in different income groups. Section 4 presents the econometric specification and data description.

[2] Economic growth is either factor driven, investment driven, or innovation driven (Raghupathi and Raghupathi, 2019)

[3] 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.

Section 5 presents the empirical investigation of the effect of foreign knowledge weighted GVC on residents' patent per capita in light of cross countries' variations in a panel of 83 countries over a time span of 30 years. Section 6 concludes and offers policy implication for lower middle and low-income countries.

2. Literature Review

This paper is blending three strands of literature aiming at analyzing the impact of foreign knowledge weighted value added on domestic innovation. The first strand is related to the positive impact of international product fragmentation on domestic production. The second strand is related to measuring knowledge spillovers as innovation input. Whereas the third strand is related to endogenizing innovation.

Within the international economics literature, a wide strand focus on value creation through international trade flows. Among others, (Feenstra and Hanson, 1996; Grossman and Rossi-Hansberg, 2008; Johnson and Noguera, 2012; Antràs and Chor, 2013; Aichele and Heiland, 2018; Lee and Yi, 2018) underly the positive impact of global value chains (GVC) participation on production. Besides the positive impact of the decline in marginal cost resulting from international product fragmentation, various models evidenced the correlation between technical innovation channeled by imports of intermediate goods and productivity (Ethier 1982; Grossman and Helpman 1991; Schmidt 1997; Kasahara and Rodrigue 2008). Despite the concern of the possible adverse effect of GVC on participating low-income countries in terms of the wages of low skilled labor, (Schmitz and Korringa, 2000; Gereffi et al, 2005; Giuliani et al, 2005) emphasize that intermediaries' trade generates learning and innovation activities. Notably, the transfer of technological knowledge through GVC is governed by the nature of the relationship and the distance among GVC participants (OECD 2017). The literature implicitly clinches the reluctance of lead countries to transfer knowledge and learning to developing countries where the former prefers to make use of the lower labor cost in the latter.

Indeed, the industry's performance in GVC enhances innovation in knowledge-based capital (KBC) (OECD 2013a and b) because the quality of products is upgraded to face the demand of foreign supply chain. However, the estimated positive impact depends chiefly on labor productivity (Corrado et al, 2013). Primarily, developing countries GVC participation is deterred by a handful of obstacles. The main pillars of linkages in value chains are rooted in preconditions mechanisms and strategic behavior (Bell and Albu, 1999; Schmitz, 2004). Likewise, a noteworthy strand in literature argue that the degree of upgrading in GVC differs according to the nature of home institutions (Werner, 2012; Barrientos et al, 2016; Pipkin and Fuentes, 2017; Kano and Tsang, 2020), as well as the business environment (Dovis and Zaki, 2020). The negative impact of institutions gap between trade partners in the MENA region for example, was emphasized using a gravity model (Karam and Zaki, 2019). Arguably, the mitigating effect of weak institutions can eventually be alleviated by gaining knowledge through participating in international networks and supply chains (Kano, 2018). Indeed, trade in services is another venue to gaining knowledge rather than goods (Grossman and Rossi-Hansberg, 2008) that will be difficult to upgrade in developing countries with prevalent distortions. Fortunately, digitalization has recently facilitated GVC participation particularly in developing countries facing high trade costs and largest distortions (World Development Report, 2020). From this strand we conclude that GVC participation can be enhanced by improving the quality of institutions.

Conceptually, knowledge diffusion literature differentiates between knowledge spillovers and technical diffusion (Zhang et al, 2019). The former is defined as a function of capital stock and is enhanced by factor mobility (Carrol et al, 1998; Barro and Sala-Martin, 2004; LeSage and Fischer, 2012); whereas the latter is modeled as a function of R&D expenditure (Coe and Helpman, 1995; Jones and Williams, 1998; Coe et al, 2009). However, R&D expenditure overestimates technical progress, therefore both patents and R&D expenditure are used to measure technical diffusion (Eaton and Kortum,1999). Due to the spatially clustered knowledge in high income countries (Marshall, 1890; Jaffe, 1998; Gassler and Nones, 2008), foreign knowledge is a chief venue for enhancing innovation in lower middle and low-income countries (Feldman, 1994; Scott, 2006). Foreign knowledge can either be transmitted through foreign direct inward investment (Pavitt and Patel, 1999) or through importing intermediate goods embedding foreign knowledge (Keller, 2002; Keller, 2004). Indeed, foreign knowledge enhances productivity through knowledge spillovers to domestic firms in developing countries. According to the IMF, foreign knowledge enhanced productivity growth by 0.4% from 1995 to 2003. In contrast to domestic R&D stock, foreign knowledge led to more than doubling domestic productivity in developing countries from 2004 to 2014 (Aslam et al. 2018).

Although knowledge spillovers are tacit and difficult to measure, imported value added embed knowledge spillovers (Maskell and Malmberg, 1999) that can be measured by foreign R&D stock endowed in partner countries. Thanks to trade in intermediaries, foreign R&D stock can be a chief input to domestic innovation (Coe and Helpman, 1995; Cowan and Jonard, 2004). Empirically, a rich stream 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). While some results imply a negative short-run effect of GVC participation on innovation in countries with low absorptive capacity (Pietcobelli, 2008; Farole and Winkler, 2014), the effect is nevertheless open for empirical investigation. Recently, the nexus between innovation and GVC is empirically tested using various regressions of cross-sectional data (Sampath and Vallejo, 2018). Results show that innovation interacts with GVC to foster learning and technological upgrading at the country level. For a sample including 74 developing countries, results unveil an association between technologically diversify exports and innovation measured by R&D investments, scientific publications, intellectual property payments, and patents per capita. From this stream, we evidence the existence of foreign knowledge spillovers in intermediaries' trade than can be measured by foreign R&D stock endowed in origin countries.

A comprehensive stream of literature endogenized innovation using patents per capita (Scotchmer and Green, 1990; Cadot and Lippman, 1995; Horowitz and Lai, 1996; O'Donoghue and Zweimuller, 2004; Bottazi and Perri, 2007; Bloom et al, 2013; Malbera et al, 2013; Tajoli and Fellice, 2018). While patent per capita is a direct innovation measure, it is considered an underestimation since some goods might be produced but not patented. On one hand, some goods have intangible nature that cannot be patented. On the other hand, although patenting is associated with higher firms' exports (Aghion et al, 2018), some inventors deliberately follow trade secrets' strategies as a substitute to patenting aiming at preserving their competitive advantage (Crass et al, 2019). Studies agree that the paramount input to patents per capita is the absorptive capacity measured by human capital stock. In the same vein, (Arrow, 1962; Gallini and Wright, 1990; Martimont et al, 2010) highlight the significance of contractual organization and resource allocation in promoting inventions.

Recent variations in domestic patenting activities across countries is explained through the different levels of development, size, and R&D (WIPO, 2021). Likewise, literature on trade and innovation agree on the positive correlation between trade openness and patents. Higher tariff rates for example, negatively affect patents for developed and developing countries alike (Vishwasrao et al, 2007). In addition, oil exports are positively associated with domestic patents for two reasons. First, oil producing countries usually file more patents to protect their oil production. Second, oil abundance induces production activities particularly in industrialized countries (Paulo and Covalheiro, 2020). Interestingly, some literature unveils the heterogenous impact of oil exports on innovation in non-industrialized countries where oil dependence induces mitigating conditions to innovation. To name a few, poor economic growth, weak institutions and corruption are potential adverse consequences of resource dependence named as the "resource curse" (Namazi and Mohamadi, 2018). From this strand, we conclude that GDP per capita, population, domestic R&D stock, trade openness and oil exports are main explanatory variables of patent per capita.

Finally, the effect of GVC participation on knowledge spillover and innovation is empirically tested by Tajoli and Fellice (2018) for developing European countries. Relying on the WIOD dataset, the study shows a positive and significant relationship between R&D stock and GDP per capita on patent per capita. Furthermore, two spillover indicators of GVC participation show a positive effect. The study also estimated a modified version to differentiate between different groups of countries according to their level of development. Results show that the significance is higher in lower income groups. However, the study excluded low-income countries. Results line up with the theoretical foundation that countries at earlier stages of development benefit more from spillovers than developed countries. The study however is not exploring the expected the interaction effect of domestic and foreign R&D stock. In addition, some explanatory variables to domestic innovation are witnessed in the literature yet their inclusion is negligible in the study namely oil exports and business environment. Furthermore, the endogeneity of GVC is not considered.

In light of the summarized theoretical and empirical strands of literature, a research gap is recognized in the effect of foreign knowledge weighted GVC on domestic innovation. The contribution of this study to the existing literature is threefold. First, the impact of the share of foreign knowledge weighted GVC on domestic patent per capita is empirically tested for countries from all income groups including a separate analysis for the understudied lower middle and low-income countries. Second, the effect of both the interaction between domestic R&D stock and foreign weighted GVC, as well as the business environment are explored. Finally, two stage instrumental variables regression is used to account for the expected reverse causality.

3. Stylized Facts

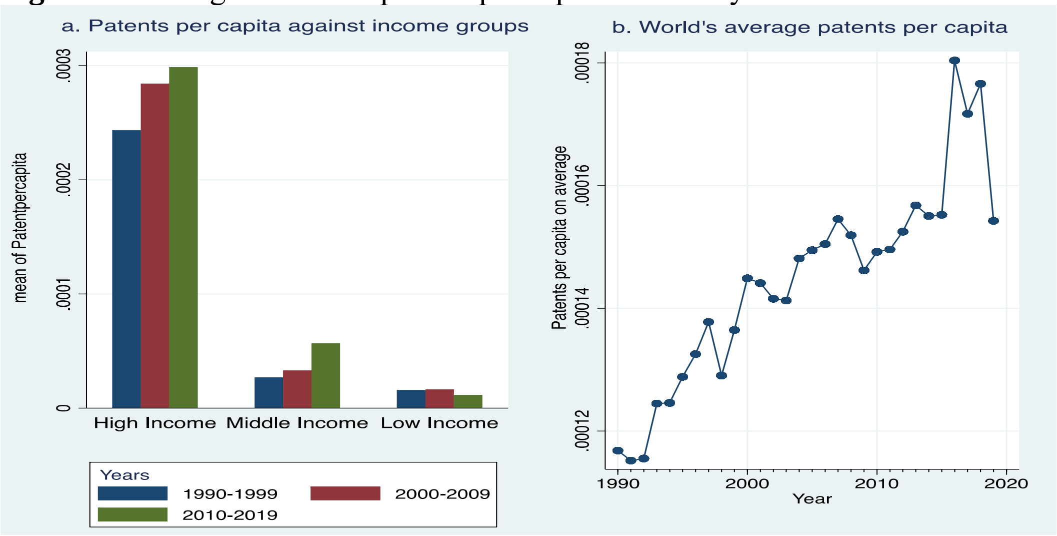
This work is testing the hypothesis that foreign knowledge spillovers through global value chains participation positively impact domestic innovation in lower middle and low-income countries in particular. The hypothesis is grounded on three stylized facts. First, innovation is spatially concentrated. Second, knowledge spillovers are strenuous to measure. Third, imported value added embed foreign knowledge to destination countries. In this section, each stylized fact is separately synchronized with dataset presentations.

3.1 Innovation is spatially concentrated

Despite the free movement of factors of production, innovation is still clustered in high income countries. This fact is depicted in figure 1 presenting the vast discrepancies in domestic innovation -measured by residents' patents per capita- between high income countries and lower income groups[4]. As shown, throughout the last three decades, high income countries are the leaders of innovation. Exceptionally, upper middle-income countries experienced the highest percentage increase in the last decade. On the other hand, lower middle and low-income countries experienced a negative growth in domestic innovation on average compared to a stagnant innovation in previous decades.

The yearly trend of world average residents' patents per capita presented in figure 1 b shows an overall positive trend in residents' patents per capita. Per capita domestic innovation is increasing by time with the exception of global crises times. We conclude from figure 1 that the positive trend of domestic innovation is solely led by high-income countries with negligible contribution of lower middle and low-income groups.

Figure 1: Average residents' patents per capita from the year 1990 till 2019



Source: Own construction based on WDI dataset

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[4] Lower middle and low-income countries are grouped in the low-income category. A list of countries with the corresponding income group is available in appendix 1.

3.2 Knowledge spillovers are strenuously measured

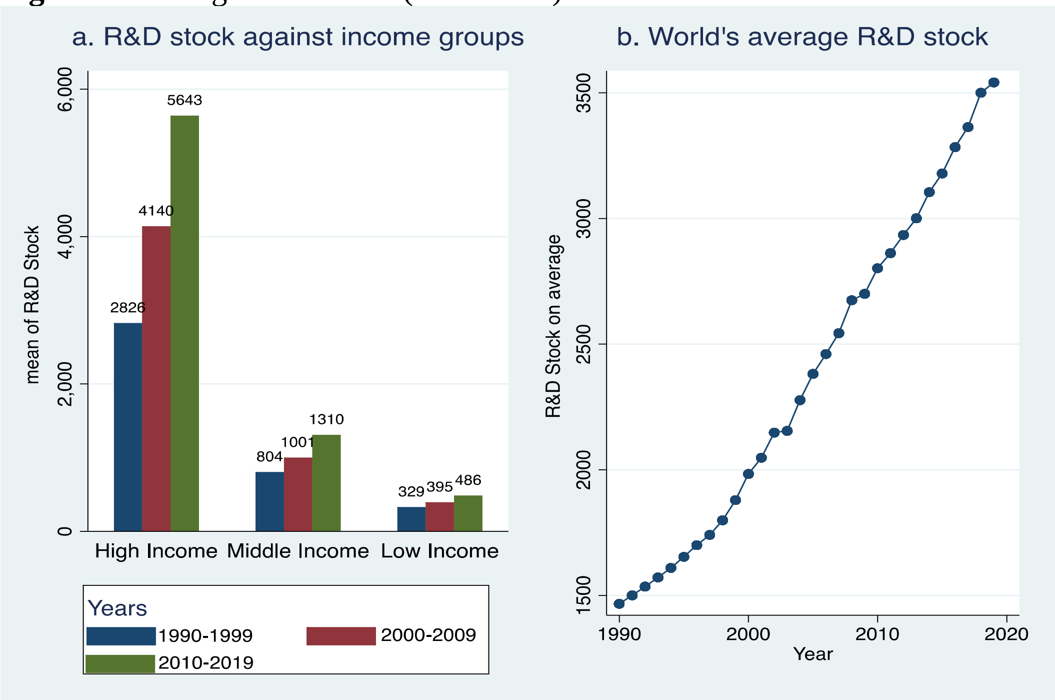
As emphasized in section2, deliberate knowledge transfer through movement of factors of production is unlikely. Therefore, we count on the tacit knowledge spillovers embedded in imported intermediate goods and services as innovation inputs.

Knowledge is difficult to measure due to its intangible nature. The foremost description for knowledge that makes it measurable, is that it is embodied in human capital. Therefore, we can indicate its value, based on R&D stock. Knowledge spillovers to lower income groups occur though importing intermediate goods from the advantaged high-income group. Consequently, R&D stock located in origin countries, embody the knowledge spillovers.

As presented in figure 2 a, high income countries are five times richer in R&D stock than upper middle-income countries on average during the last decade. Whereas upper middle-income countries are three times as rich as lower middle and low-income countries in R&D stock on average during the last decade. Notably, R&D stock is the chief input for innovation and is likely to be spatially clustered as presented in figure 2 a. Figure 2 b depicts the consistently upward trend of R&D stock across time.

The above two presented facts lead us to the third fact that lower income groups have the highest advantage in terms of innovation from foreign knowledge spillovers through imports of intermediate goods. Since both innovation output (patent per capita) and innovation input (R&D stock), are clustered in one income group, then for the other income groups to contribute to innovation, the knowledge embedded in foreign R&D stock has to be transferred -spilled over- through importing intermediate goods and participating in global value chains.

Figure 2: Average R&D stock (1990-2019)



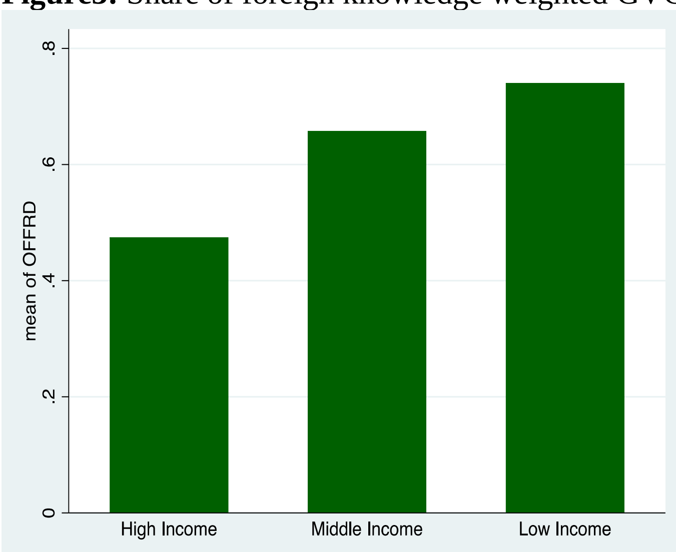
Source: Own construction based on WDI dataset

Figure 2 shows the potential tacit knowledge for lower middle and low-income countries available in higher income origin countries provided the former is engaged in international production networks and import intermediate goods from the latter.

3.3 Foreign value-added absorbed embed foreign knowledge to destination countries

Indeed, the less the countries' endowment with domestic R&D stock, the higher the foreign knowledge spillovers. Therefore, when foreign value added imported is weighted with partners' countries (origins) R&D stock, the spillover variable is expected to be higher at lower income countries. Figure 3 presents the share of foreign knowledge weighted value added on average in the different income groups from 1990 to 2019. Although high income countries participate more in GVC, figure 3 shows that the share of foreign knowledge through GVC is highest at low-income countries and lowest for high income countries.

Figure3: Share of foreign knowledge weighted GVC from 1990 to 2019[5]



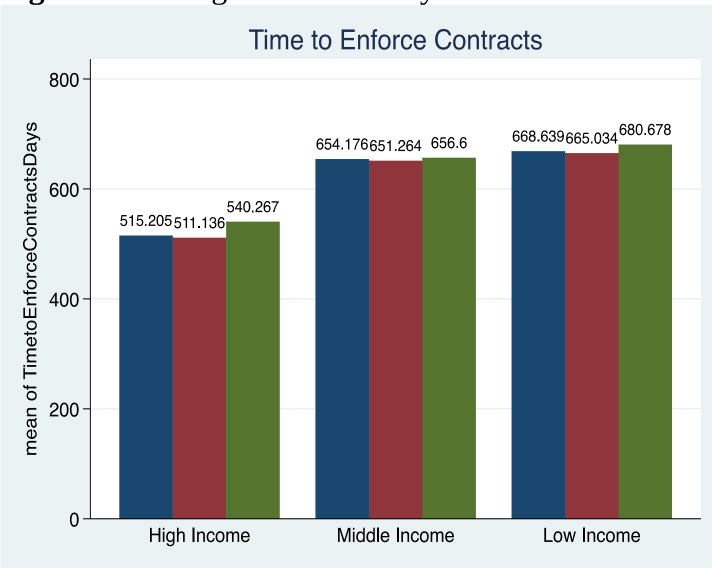
Source: Own calculations based on merging EORA26 and WDI datasets

The data presented suggest a positive impact of GVC participation in terms of domestic innovation particularly in lower middle and low-income countries. Since auxiliary business environment conditions impacts domestic innovation, we include data on the time to enforce contracts as an indicator of the quality of the business environment.

Figure 4 presents the average time to enforce contracts in different income groups in the previous three decades. As presented, high income groups are privileged with enhanced busines environment hown by the lowest number of days to enforce contracts.

[5] Measurement details are provided in section 4.

Figure 4: Average number of days to enforce contracts from the year 1900 till 2019



Source: Own calculations based on World Bank Doing Business Dataset

4. Methodology and Data

4.1 Measuring the share of foreign knowledge in Global Value Chains

The study is focused on the effect foreign knowledge absorbed through backward linkages to GVC on domestic innovation. Precisely, the variable of interest is the share of foreign knowledge weighted GVC. From the numerous GVC measures, we use the Feenstra and Hanson (1996) offshoring indicator measuring the share of foreign value added absorbed through imported intermediate goods to the total value added of intermediate goods including the domestic value added. We construct the variable of interest by weighting the offshoring index with the share of R&D stock in origin countries (exporters of intermediaries). The constructed variable of interest named OFFRD is the measure of the share of foreign knowledge weighted value added in total knowledge weighted value added. Hence, for each destination (importer) country, each value added imported from an origin country is multiplied with the corresponding R&D stock in the origin country. Then, the summation is divided by the total R&D weighted value added including the weighted domestic value added.

Formula (1) presents the calculation of the share of foreign knowledge weighted GVC.

$$\text{OFFRD}it = \frac{\sum_{it}^{jt} VA\ ij * RDj}{(\sum_{it}^{jt} VA\ ij * RDj\ ) + (DVAi * RDi)} \qquad (1)$$

Where, i is the destination (importing) country and j is the origin (exporter) country, t is time, VA is the imported value added, DVA is the domestic value added, and RD is the R&D stock.

To construct the variable of interest, we merge the input output value added tables in the UNCTAD-EORA26 dataset (Lenzen et al., 2012 and 2013), with R&D stock data from the

World Development Indicators database. In EORA26 database, all countries are aggregated to a common 26 sector[6] classification. The database includes 189 countries from 1990 till 2019[7].

4.2 Econometric specification

Following Tajoli and Felice (2018), the econometric model addresses the hypothesis that GVC participation has driven foreign knowledge spillover effect reflected in increasing residents' per capita patents across countries. The model aims at emphasizing the foreign learning effect of backward participation linkages to GVC. The contribution of our model to the original one is threefold. First, it includes a larger panel in terms of number of countries and for a longer time span. The original model included European developing countries however we include countries from across different regions and different income groups. Second, our model relies on a different dataset in constructing the share of foreign knowledge weighted GVC indicator. To our knowledge, this is the first paper using the EORA26 dataset in measuring knowledge weighted GVC variable. Third, we expand the model to include different effects explaining the nexus between GVC and innovation. Particularly, we account for the interaction between domestic and foreign R&D stock effect, business environment effect, and the heterogenous effect on low and middle low-income groups. As emphasized, the constructed share of foreign knowledge weighted GVC indicator is the variable of interest whereas residents' per capita patents is the dependent variable. Formula (2) presents the base line model specification.

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

Where,

PAT_{it} is the residents' patent per capita in country i at time t expressed in logarithm.
$OFFRD_{it}$ is the share of foreign knowledge weighted GVC in country i at time t.
X_{it} is a set of control variables including domestic R&D stock; GDP per capita controls for country's level of development; total population controls for the size of the country; tariffs[8] control for trade openness; oil exports as a percentage of GDP controls for oil exporting countries.
u_i is a time invariant fixed effects variable controlling for the across countries' unobserved heterogeneity.
ε_{it} is a residual error term.

As a further analysis, we construct an interaction term between OFFRD and domestic R&D stock using double demeaning process for both variables. The interaction term is then added to the regression as an explanatory variable to examine the significance and the effect of the interaction on the dependent variable. The expanded regression is presented in equation 3.

$$PAT_{it} = b_0 + b_1 \ OFFRD_{it} + b_2 \ X_{it} + b_3 Interaction_{it} + u_i + \varepsilon_{it}$$
(3)

[6] The 26 aggregated sectors are listed in appendix 2.
[7] Recently updated to country tables till the year 2016.
[8] Applied weighted mean tariff rate on manufactured products.

Where PAT_{it} , $OFFRD_{it}$, X_{it} , u_i, and ε_{it} hold the same definitions as in equation 2. Equation 4 presents the $Interaction_{it}$ measurement.

$$Interaction_{it} = [OFFRDit - \ mean(OFFRDi)] * [RDstockit - mean(RDstocki)] \qquad (4)$$

The inclusion of the interaction term is informative in explaining the effect of each variable on the dependent variable as the other variable changes noting that both variables are inputs for domestic innovation.

Since considerable literature suggests an association between innovation and the business environment, the model is further extended to explore the effect of the business environment on residents' patent per capita. The number of days to enforce contracts is the business environment indicator. Equation 5 presents the specification when the business environment variable is included.

$$PAT_{it} \ = \ c_0 + \ c_1 \ OFFRD_{it} + \ c_2 \ X_{it} + c_3 TimetoEnforceContracts_{it} + \ u_i + \ \varepsilon_{it} \qquad (5)$$

Where PAT_{it} , $OFFRD_{it}$, X_{it} , u_i, and ε_{it} hold the same definitions as in equation 2 and $TimetoEnforceContracts_{it}$ is the number of days to enforce contracts and is expressed in logarithm.

Since residents' per capita patents and time to enforce contracts are expressed in logarithm, c_3 is the business environment elasticity of domestic innovation. Indeed, the elasticity will vary in accordance with the income level. To untangle the heterogenous effect of foreign knowledge weighted GVC on lower middle and low-income countries, all the fixed effects regressions presented in equation 2 to 5 are repeated on a selected sample -according to the World Bank classification- of 19 countries. Indeed, lower income groups are expected to benefit more from foreign knowledge transmitted from countries with higher R&D stock endowment. Finally, due to the expected endogeneity of GVC, we use two stage instrumental variables least squares regression. The average of partner countries' R&D stock and the average of institutions are used as instruments for the variable of interest.

Given the baseline model specification in equation 2 with endogenous $OFFRD_{it}$, the first stage regression is presented in equation 6.

$$OFFRD_{it} \ = \ \beta_o + \ \beta_1 Z_{it} + \ \beta_2 X_{it} + \ v_{it} \qquad (6)$$

Where,
Z_{it} is a vector of the two instrumental variables: the average of partners' R&D stock in country i at time t, and the average of institutions indicators in country i at time t.
X_{it} is a vector of the same control variables in equation 2
v_{it} is a residual error term.

In the second stage regression, the dependent variable is regressed on the estimated effect of the instrumental variables along with the control variables. Overidentification restriction test is used to guarantee the instrumental variables' strengths and hence robustness.

Later, we plan to study non-residents' patent per capita as the dependent variable and include relevant explanatory variables affecting foreign patents like trade agreements, WTO membership, and foreign investments.

4.3 Data

Based on the availability of patent data, our sample consists of 83 countries. All countries in the sample are available in the input output tables in EORA26 dataset. We include all the available years at the time of the data collection process. The time frame is 30 years from 1990 till 2019. The advantage of the EORA26 dataset is that it includes a wide range of countries allowing the inclusion of lower middle and low-income countries. However, it has limitations stemming in the assumption of constant production function for all industries. In addition, some countries have estimated proxies. Nevertheless, it is a widely used dataset in GVC measurements. It is used in recent reports of the World Bank, UNCTAD, and IMF among others.

We rely on the World Development indicators (WDI) dataset to measure the residents' patent per capita which is the dependent variable. Both the patent applications for residents and the total population variables are available in the WDI. We measure the dependent variable for the 83 countries with patent data availability. R&D stock is the number of researches working in R&D per million of the population relying on WDI and the USI Stateexports datasets. GDP per capita (constant 2010 US$), tariffs on manufactured products, and oil exports as a percentage of GDP, rely on the WDI. Time to enforce contracts relies on the World Bank historical doing business dataset. The institution's variable is the average of the six world governance indicators[9] available in the World Bank World Governance Indicators dataset

5. Empirical Results

Results of the effect of the variable of interest -foreign knowledge weighted offshoring[10]- on residents' per capita patents are reported in tables 1 to 5. Table 1 presents the results of the variable of interest as well as the control variables, on residents' per capita patents. Column 1 indicates that the effect of knowledge weighted GVC on residents' per capita patents is positive yet insignificant. However, when we control for domestic R&D stock, GDP per capita and the population, the effect of foreign knowledge weighted GVC on residents' patent per capita is positive and significant (column 4). As presented in column 4, a 1% increase in foreign knowledge weighted offshoring results in a 0.24% increase in domestic per capita patents. Nevertheless, significance decreases when we control for tariffs (column 5) and oil exports (column 6). Controlling for oil exports results in an insignificant effect of foreign knowledge weighted offshoring on residents' patent per capita. Notably, oil exporting countries are expected

[9] Including voice and accountability, political stability / no violence, government effectiveness, regulatory quality, rule of law, and corruption control.

[10] Offshoring and GVC are used interchangeably to denote the variable of interest. It is referred to as OFFRD in all tables.

to have lower GVC participation in terms of value added. They are expected to participate in downstream activities in the international production network. Precisely, they contribute to the international product fragmentation with a primary sector that is far from the final demand. Nevertheless, oil producing (net exporters) countries are expected to incur domestic production and therefore it is intuitive that oil exports positively affect domestic patents as presented in column 6. Indeed, the higher the production of oil, the higher the domestic production especially in industrialized countries, and therefore the higher the filing for domestic patents. [11]

The coefficients' signs of the control variables are consistent with trade and innovation theoretical grounds. As presented in column 2, domestic R&D stock has a significant and a positive effect on domestic innovation. Yet, significance decreases when controlling for the size of the country proxied by the population. Indeed, domestic R&D stock is the chief input to innovation. Collinearity between R&D stock and the population is expected particularly in high income countries. Concisely, the former is a measure of the number of researches working in R&D and therefore it is expected to increase with the latter assuming efficient allocation of resources. As presented in column 3 to 6, GDP per capita has a highly significant and positive effect on domestic innovation. Indeed, the higher the development level of the country the higher the innovation and the closer the country to the technological frontier. As for trade openness, undoubtedly less trade barriers facilitate across borders' knowledge flows, and therefore results in more inventions and consequently higher patents. The negative and significant effect of tariffs on residents' patent per capita presented in columns 5 and 6 align with the literature advocating the positive impact of trade on innovation. As presented, a 1% increase in tariff rate results in a 0.012% decline in residents' patent per capita.

In summary, the effect of foreign knowledge weighted offshoring on residents' patent per capita is positive yet insignificant for the sample containing countries of all income groups. However, it is important to note that the sample under study is not well balanced in regard to income groups. Due to the constraint of data availability, only 23% of the sample under study is for lower middle and low-income groups. Accordingly, results are inevitably biased towards high income countries containing the majority of the sample. To overcome the biasness, lower middle and low-income countries are singled out later in this section to untangle the heterogenous effect in accordance with the varying income level of countries.

[11] Residents' patent per capita, R&D stock, GDP per capita, and the population are expressed in logarithms in all regressions.

Table 1: The effect of foreign knowledge weighted GVC measure on residents' patents per capita

	(1)	(2)	(3)	(4)	(6)
	Residents' per capita patents	Residents' per capita patents	Residents' per capita patents	Residents' per capita patents	Residents' per capita patents
OFFRD	.003	.514***	.283***	.236***	.137
	(.077)	(.086)	(.09)	(.089)	(.088)
RD Stock		.194***	.092***	.033	.041*
		(.016)	(.02)	(.023)	(.022)
GDP per capita			.501***	.463***	.237***
			(.062)	(.062)	(.065)
Population				.812***	.284*
				(.147)	(.153)
Tariffs					-.012***
					(.001)
Oil Exports					.004**
					(.002)
Constant	-4.602***	-6.206***	-7.367***	-12.654***	-7.874***
	(.046)	(.141)	(.199)	(.979)	(1.065)
Observations	2490	2490	2490	2490	2490
R-squared	0	.057	.082	.093	.132
Country FE.	Yes	Yes	Yes	Yes	Yes
No. of countries	83	83	83	83	83

Standard errors are in parenthesis
**** $p<.01$, ** $p<.05$, * $p<.1$*

To further explore the determinants of residents' patents, an interaction variable between foreign knowledge weighted GVC and domestic R&D stock is constructed using double demeaning and included in the regression as an explanatory variable. Table 2 presents the results of the interaction on residents' patent per capita. Results show that the inclusion of the interaction variable increases the significance as well as the positive effect of foreign knowledge weighted offshoring on residents' patent per capita. As presented in column 2, a 1% increase in foreign knowledge weighted offshoring results in a 2% increase in residents' patent per capita. Furthermore, the significance as well as the positive effect of domestic R&D stock on residents' patent per capita increases. Colum 2 shows that a 1% increase in domestic R&D stock results in a 0.13% increase in residents' patent per capita.

Nevertheless, the interaction term is negative and highly significant. The negative impact of interaction lies in the substitutability between foreign and domestic R&D stocks as inputs for innovation. As foreign R&D stock increases (decreases), the impact of domestic R&D as an input for domestic innovation decreases (increases). Adding the interaction term however, neither alters the effect nor the significance of other control variables namely GDP per capita, population, tariffs, and oil exports.

Table 2: The effect of interaction between knowledge weighted GVC and domestic R&D stock on residents' patents per capita

	(1)	(2)
	Residents' per capita patents	Residents' per capita patents
OFFRD	.137	1.998***
	(.088)	(.201)
RD Stock	.041*	.132***
	(.022)	(.024)
Interaction		-.477***
		(.046)
GDP per capita	.237***	.201***
	(.065)	(.064)
Population	.284*	.287*
	(.153)	(.15)
Tariffs	-.012***	-.011***
	(.001)	(.001)
Oil Exports	.004**	.003*
	(.002)	(.002)
Constant	-7.874***	-9.608***
	(1.065)	(1.056)
Observations	2490	2490
R-squared	.132	.168
Country FE	Yes	Yes
No. of countries	83	83

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

To conclude, the embedded foreign R&D stock in the knowledge weighted offshoring variable indeed interact with domestic R&D stock. As foreign knowledge spillover increases through GVC participation, the effect of domestic knowledge (domestic R&D stock) decreases; and as the domestic knowledge (R&D stock) increases, the effect of the foreign R&D on domestic innovation decreases.

Table 3 presents the business environment effect on residents' per capita patents. As shown in column 3, time to enforce contracts is negatively and significantly correlated with residents' patent per capita. A 1% increase in the number of days to enforce contracts[12] results in a 2.45%

[12] Time to enforce contracts in expressed in logarithm.

decrease in residents' patent per capita. Indeed, the longer the time it takes to enforce contracts, the less the patents' applications. Notably, adding the business environment variable results in an insignificant foreign knowledge weighted GVC like the baseline regression presented in column 1. Likewise, all control variables preserve their significance and effect like the baseline regression results. Indeed, the positive effect of the variable of interest is highest in significance when foreign and domestic R&D stock interact together as presented in column 2.

Table 3: The effect of business environment on residents' patents per capita

	(1)	(2)	(3)
	Residents' per capita patents	Residents' per capita patents	Residents' per capita patents
OFFRD	.137	1.998***	.117
	(.088)	(.201)	(.089)
RD Stock	.041*	.132***	.039*
	(.022)	(.024)	(.022)
Interaction		-.477***	
		(.046)	
GDP per capita	.237***	.201***	.261***
	(.065)	(.064)	(.067)
Population	.284*	.287*	.279*
	(.153)	(.15)	(.153)
Tariffs	-.012***	-.011***	-.012***
	(.001)	(.001)	(.001)
Oil Exports	.004**	.003*	.004**
	(.002)	(.002)	(.002)
Time to Enforce Contracts			-2.45*
			(.136)
Constant	-7.874***	-9.608***	-7.246***
	(1.065)	(1.056)	(1.12)
Observations	2490	2490	2490
R-squared	.132	.168	.133
Country FE	Yes	Yes	Yes
No. of countries	83	83	83

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

To conclude, results of regressions for all countries in the sample are fivefold. First, the positive effect of foreign knowledge weighted GVC on residents' patent per capita is insignificant unless interaction of foreign and domestic R&D stocks is accounted for. Second, domestic R&D stock has a positive and significant effect -increases when the interaction term is accounted for-on residents' patent per capita. Third, the interaction term between foreign and domestic R&D

stocks is significant on residents' patent per capita. The negative effect is explained by the substitution effect of the two interacting variables as inputs to innovation. Fourth, business environment matters for innovation. There exists a negative and significant relationship between the time (days) to enforce contracts and residents' patent per capita. Fifth, GDP per capita, population, oil exports positively and significantly affect residents' patent per capita whereas tariffs has a negative and significant effect.

Indeed, foreign knowledge spillover effect is expected to vary with varying levels of R&D stock at different levels of development. Since high income countries are the exporters of technology, it is certainly unexpected that they gain from foreign knowledge from lower income group countries with impotent technology. Indeed, the lower the level of development, higher the gain of foreign knowledge spillover through GVC. Therefore, investigating the effect on lower middle and low-income countries exclusively is worthwhile.

Table 4 presents the results of the effect of foreign knowledge weighted GVC on residents' patent per capita in lower middle and low-income countries. For comparative reasons, column 1 presents the baseline model specification's results on all countries. Whereas results of the same model on lower middle and low-income countries are presented in columns 2 to 4. As presented in column 2, the variable of interest is positive and highly significant on residents' patent per capita. As presented, a 1% increase in foreign knowledge weighted offshoring results is a 0.8% increase in residents' patent per capita. In addition, the positive effect of domestic R&D stock is more significant compared to the results of the whole sample. On the other hand, GDP per capita and population turns to insignificant. This means that in lower middle and low-income countries, neither the level of development nor the population are stimulating factors to innovation. Indeed, foreign knowledge weighted GVC is the chief stimulating factor to domestic innovation for this particular income group. Yet, the effect of tariffs is still significant and negative showing that trade liberalization positively affects domestic innovation with no distinction in varying income group levels.

Column 3 presents the results of the interaction between foreign and domestic R&D stock in lower middle and low-income countries. As shown, including the interaction variable results in a more than 4 times increase of the effect of foreign knowledge weighted GVC on residents' patent per capita. A 1% increase in foreign knowledge weighted GVC results in a 4.2% increase in residents' patent per capita compared to a 2% when the interaction variable is added for the whole sample as presented in table 2. Results indicate that the positive effect of foreign knowledge weighted GVC in lower middle and low-income countries, is two times the effect for all countries. Likewise, the inclusion of the interaction variable results in a higher and more significant positive effect of domestic R&D stock on residents' patent per capita. On the other hand, the interaction variable is still negative and significant due to the substitution effect between foreign and domestic R&D stock as inputs for innovation. Nevertheless, the coefficient of the interaction is more than doubled in lower middle and low-income countries compared to the whole sample. Including the interaction term does not alter the insignificance of GDP. However, the population effect is altered to negative and significant. The negative effect of the size of the country on residents' patent per capita is explained by the increased distortions with larger population in lower income groups in particular. This phenomenon is not vivid in the sample of all countries where population consistently has a positive and significant effect on domestic innovation. On the other hand, tariffs preserve the negative and significant relationship with residents' patent per capita, whereas oil exports show insignificance when the interaction variable is included.

Column 4 presents the results of the business environment effect on domestic innovation in lower middle and low-income courtiers. As presented, the number of days to enforce contracts has a negative and a significant effect on residents' patent per capita. A 1% increase in the number of days to enforce contracts results in a 1.1% decrease in residents' per capita patents. This effect is lower than that for all countries; yet its significance is higher in lower middle and low-income countries. Interestingly, including the business environment variable leads to an insignificant effect of domestic R&D stock, whereas GDP per capita preserves its insignificance. Likewise, the effect of the population on innovation is insignificant when including the business environment variable. Consistently, tariffs have a negative and significant effect on residents' patent per capita. As presented in columns 3 and 4, oil exports have an insignificant effect on domestic innovation in lower middle and low-income countries which signals the resource dependence of oil producers in these income groups.

Table 4: The effect of knowledge weighted GVC on residents' patents per capita in lower middle and low-income countries

	(1)	(2)	(3)	(4)
	Residents' per capita patents	Residents' per capita patents	Residents' per capita patents	Residents' per capita patents
OFFRD	.137 (.088)			
OFFRD Low Income		.809*** (.153)	4.224*** (.608)	.665*** (.163)
RD Stock	.041* (.022)	.116** (0.058)	.476*** (.084)	.085 (.059)
Interaction			-.916*** (.158)	
GDP per capita	.237*** (.065)	.112 (.137)	.091 (.133)	.168 (.138)
Population	.284* (.153)	-.445 (.338)	-.858** (.336)	-.296 (.341)
Tariffs	-.012*** (.001)	-.01*** (.002)	-.009*** (.002)	-.01*** (.002)
Oil Exports	.004** (.002)	.006* (.004)	.002 (.004)	.005 (.004)
Time to Enforce Contracts				-1.068** (.42)

Constant	-7.874***	-3.576	-4.613**	-1.656
	(1.065)	(2.187)	(2.132)	(2.304)
Observations	2490	570	570	570
R-squared	.132	.166	.215	.176
No. of countries	83	19	19	19

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

To sum up, exploring the effect on lower middle and low-income countries revealed considerable significance of foreign knowledge weighted GVC on domestic innovation. Indeed, in this particular income group, foreign knowledge weighted GVC as well as the business environment are the chief variables affecting residents' patent per capita. Furthermore, compared to the results on the whole sample, the effect of the control variables is heterogenous in lower middle and low-income countries except for tariffs having a consistent negative and significant relationship. Conversely, GDP per capita, population, oil exports have an insignificant effect on domestic innovation in lower middle and low-income countries unlike their significant effect at higher income level countries shown in the general results on all income levels.

Finally, applying the Durbin Watson and Hausmann tests resulted in a p-value of zero. Therefore, the null hypothesis of exogeneous variables is rejected. This endogeneity is due to the two-way possible causal relationship between domestic innovation and GVC participation. To ensure robustness, table 5 presents the results of the instrumental variables two-stage regression. Column 1 presents the results of using the average of the foreign R&D in partner countries as an instrumental variable for the variable of interest. As shown, using the instrumental variable results in a positive and significant effect on residents' patent per capita. Likewise, all control variables preserve significance and consistent sign as the baseline one stage regression. The first stage test leads a minimum eigenvalue statistic of 52.3 which is significantly higher than the critical values of 19.9, 11.59, 8.7 and 7.2 at significance levels of 10%, 15%, 20%, and 25% respectively. Therefore, we reject the null hypothesis of weak instruments. In addition, to verify the strength of instrument, average value of institutions is added as an instrumental variable. Column 2 presents the two stage least squares regression results when two instrumental variables are used for the variable of interest. Furthermore, the Sargan's test p-value of 0.34, verifies the strength of instruments using the overidentification restrictions' test. Consequently, model robustness is guaranteed.

Table 5: Two stage least squares regression

	(1)	(2)
	Residents' per capita patents	
	IV Partners' RD	IV Institutions and partners' RD
OFFRD	2.075***	2.16***
	(.369)	(.364)
RD Stock	.517***	.526***
	(.041)	(.041)
GDP per capita	.772***	.784***
	(.061)	(.061)
Population	.333***	.342***
	(.044)	(.043)
Tariffs	-.008***	-.008***
	(.003)	(.003)
Oil Exports	.007***	.007***
	(.002)	(.002)
Constant	-14.718***	-14.945***
	(.998)	(.986)
Observations	2490	2490
R-squared	.47	.453
No. of countries	83	83

kStandard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

The results presented in tables 1 to 5 show that foreign knowledge weighted GVC impacts domestic innovation particularly for lower middle and low-income countries. Likewise, the interaction between foreign and domestic R&D stock has a negative and significant coefficient. As one variable increases, the positive effect of the other variable on domestic innovation decreases. This is due to the substitution effect between the two variables as inputs for innovation. Nevertheless, the interaction effect increases the significance and the coefficients of both foreign knowledge weighted GVC and domestic R&D stock with higher influence in lower income countries. Moreover, domestic R&D stock, GDP per capita, population and oil exports significantly affect domestic innovation positively. However, the effect varies for lower middle and low- income countries where GDP per capita, population, and oil exports loses significance. Consistently, tariffs negatively affect domestic innovation at all income levels. Finally, robustness is guaranteed through applying a two stage least squares regression using average institutions and average partners' R&D stock as instruments to the variable of interest.

6. Conclusion

This paper provides an intersection between GVC participation and innovation. It highlights the externality learning effect of GVC and assesses the opportunity for developing countries to catch up to the technological frontier through participating in international product fragmentation. Results show positive significance of foreign knowledge weighted GVC on residents' patent per capita for lower middle and low-income countries. Furthermore, results show a significant and negative association between time to enforce contracts and resident patent per capita for all countries. In addition, results show robustness when two stage instrumental variables regression is employed. Likewise, this paper is contributing to the post COVID-19 controversial discussion on the trade-off of reshoring activities. Meanwhile, this study argues that GVC participation is a vehicle of international knowledge spillovers accelerated with an unyielding business environment.

Inevitably, some relevant ideas are beyond the scope of this paper and are therefore areas for further research. First, the effect of the share of domestic value added absorbed and exported on innovation is not diagnosed. This paper is particularly focused on backward participation linkages to GVC. Second, the sectoral heterogenous effect on innovation is not analyzed. Our model is considering the effect on the aggregate level for all sectors. Indeed, studying the relationship on the sectoral level unveils the type of technological change which is informative in regard to countries' factor endowments.

On a policy perspective, our recommendations are fourfold. First, the negative and significant association between tariffs and innovation necessitates trade liberalization targeted policies. Second, since the quality of institutions is an important determinant of GVC, institutions' evolution polices are compulsory to foster the participation of developing countries and enhance the foreign learning effect. Third, the significant effect of business environment requires policies to the end of business environment convalescence. Finally, since domestic R&D stock positively affect domestic innovation, increasing the number and quality of researches is key to enhancing innovation. This necessitates human capital investment policies to the end of improving the quality of education by enhancing the research skills of students in higher education stages. Clearly, our policy recommendations are directed towards developing countries with prevalent mitigating conditions.

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Appendix 1

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

Appendix 2

Sector classificaton in Eora26

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 Restraurants
19 Transport
20 Post and Telecommunications
21 Finacial Intermediation and Business Activities
22 Public Administration
23 Education, Health and Other Services
24 Private Households
25 Others
26 Re-export & Re-import