

# How Do Productivity Benefits Spill Over Across Firms? Explorations in a Heterogeneous Firm Applied General Equilibrium Trade Model\*

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## Abstract

Considerable diffusion of technology occurs via global trade and foreign direct investment (FDI) while firm heterogeneities cause considerable production heterogeneities. Hi-tech products and investment goods of differentiated varieties from emerging and developed economies are vehicles of superior technology. Given this stylized evidence, we analyse factors facilitating (or inhibiting) technological spillover to domestic firms in the host nations in a counterfactual scenario of a Trans-Pacific-Partnership (TPP) deal. By using a *mixture interface* of global computable general equilibrium (CGE) models of FDI (GTAP-FDI) and *firm heterogeneity model of Global Trade Analysis Project*, GTAP Heterogeneous (GTAP-HET), we calibrate impacts of trade and FDI spillovers on: (i) global production, (ii) trade patterns, (iii) welfare and (iv) regional productivity gains. Importance of regional trade agreements and policy for productivity spillovers is highlighted.

**Keywords:** GTAP, CGE, firm heterogeneity, FDI, productivity spillover, TPP

**JEL Classification:** F11, F21, O33, O24

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## 1. Introduction

Globalization and technology transmission is important for growth and development. Considerable diffusion of technology occurs between source and destination regions via trade embodiment as well as a disembodied tacit way and foreign direct investment (FDI). We explore the aspects of FDI-driven technological spillover to domestic firms in the host nations in a counterfactual scenario of a Trans-Pacific-Partnership (TPP) deal, precursor to the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP). The importance of this study for other such groups of countries, say, for Central European economies (CEE), is quite significant because deep trade agreements affect FDI through trade. The effects depend on the sectoral composition and the structure of the host country and its income level (Ullah *et al.*, 2022). Meriküll *et al.* (2011) discussed that middle-income CEE can have scope for regional productivity spillovers from high-income EU countries via trade and FDI to achieve convergence from external technology. Merlevede and Purice (2019) is an important study along similar lines showing cross-border spillovers to local firms in Central and Eastern Europe via FDI after EU integration. Pica and Sicari (2022) show that differences in regional convergence in CEE vis-à-vis the Southern European nations can be attributed to degree of integration and innovation. Attracting FDI for reducing the technology gap is crucial. The role of MNEs is important, as are the roles of “ownership of capital” and the capital flows (Hanousek and Kocenda, 2020; Vujanović *et al.*, 2021; Herman, 2022). The aspect of innovation, R&D and adoption of knowledge-capital by building up human capital also matter (Das, 2002; Eaton and Kortum, 1999 and 2002; Lucas, 2015). FDI and trade facilitate knowledge transfer via intra-industry trade, more so with vertical or horizontal integration via production networks or global value chains (GVC); see Antras (2020), Antras and Gortari (2020), Procházková Ilinitchi *et al.* (2021). Almunia *et al.* (2021) is quite an important study for firm-level exports during domestic-demand shocks such as COVID-19.

As an illustrative counterfactual, we examine the impact of a potential Trans-Pacific Partnership (TPP) agreement on FDI and productivity spillovers using a global computable general equilibrium (CGE) model capturing interactions. Specifically, we use the Global Trade Analysis Project (GTAP) model. There are *two parts* to our analysis to *interface* the FDI model and the firm heterogeneity model couched in the GTAP framework. In the *first part*, we obtain the (endogenous) *productivity change* in response to the TPP (Regional Comprehensive and Economic Partnership, RCEP) policies such as tariff liberalization and FDI using the FDI model of the GTAP, *i.e.*, *GTAP-FDI*, based on Lakatos and Fukui (2014). In the *second part*, we implement this *productivity change as a policy shock* to analyse the effects using the *firm heterogeneity model of the GTAP* (henceforth, GTAP-HET), based on Akgul *et al.* (2016). The GTAP-HET model is a useful platform to investigate the productivity spillover via trade-led productivity changes as well as extensive margin effects. The GTAP-HET (i) models self-selection of firms into domestic and export markets based on productivity differences, (ii) encapsulates the trade-growth nexus along the extensive margin, (iii) features consumer love of variety, and (iv) models fixed costs on domestic and export markets.

Although the TPP is controversial (after USA's withdrawal in January 2017), as a regional integration scheme it is relevant from a policy research perspective. This is based on several accounts. TPP is a mega-trade deal signed by twelve Pacific Rim nations, comprising 40% of the world economy with potential strategic and economic benefits. The reason for retreating was primarily driven by an apprehension of a decline in manufacturing and machinery, causing unemployment and inequality. The TPP still strongly progressed among the non-US members with possibilities of China joining it, culminating into the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP). As the TPP covered tariffs on goods and services, e-commerce rules, labour standards, technology-intensive goods, biologics, technology and trade secrets, it is important to make a policy impact analysis and consider productivity spillovers. We purport to analyse the potential effects of the TPP *from a counterfactual perspective, i.e., what if* the TPP had taken place without any obstacle (Li *et al.*, 2018, Narayanan *et al.*, 2016; Petri *et al.*, 2014 and 2021). To study the impact, trade openness, FDI and spillovers on top of firm-heterogeneity are also pertinent.<sup>1</sup> For example, under the presidency of Donald Trump, neo-protectionism emerged, leading to a trade war and breakdown of negotiations. “*What if*” analysis of the foregone policies as well as understanding the impacts on FDI in a complex global production network is informative (Falvey and Foster-McGregor, 2022; Herman, 2022; Olney, 2022; Anderson and Yotov, 2016).

Here, the rationale to *link* the GTAP-FDI and GTAP-HET models is that depending on firm-level differences in productivity spillovers via trade and/or FDI, *productivity thresholds* change in firms across sectors. FDI and trade cause technology flows via vertical or horizontal integrations and enable them to produce heterogeneous varieties. Deeper integration such as the TPP could enhance gains from trade via growth effects (Wignaraja *et al.*, 2015). As Petri *et al.* (2014 and 2021) considered the economic consequences and convergence among the participating regions under the TPP, our motivation lies in gains via spillovers, simulating resource allocation as well as growth effects of trade. We consider heavy machinery as a representative source of such technology transmission via trade intermediates (Keller, 2004; Das, 2002 and 2015). Because technology is disseminated through technology-intensive goods via backward and forward linkages, the CGE model is quite suitable for this inter-sectoral transmission.

Section 2 offers an overview and gaps in the literature. Section 3 introduces the GTAP-FDI (Lakatos and Fukui, 2014) and GTAP-HET (Akgul *et al.*, 2016) models. Section 4 describes database and simulation designs. Section 5 presents results and Section 6 concludes.

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<sup>1</sup> With the CPTPP, it is more pertinent to study the alternative impacts under previous scenarios.

## 2. Review of Issues

### 2.1 Literature

For linking the sectoral productivity differences and macroeconomic outcomes in the presence of MNEs, we focus on *two broad strands of literature* in FDI, growth and technology, namely, *macro aspects* and the *micro-angle*, where firm-level heterogeneities matter. Current research analyses the importance of inventive activity, role of technology and technological capability (Das, 2002 and 2015). Bruno *et al.* (2017) find in a meta-analysis that “economic benefits” at the macro and micro (firm) level are conditional upon clients’ institutional, financial and human capital and inter-sectoral linkages with strong heterogeneities in these factors (Das, 2014a and 2019; Keller, 2004).

Considering the heterogeneous firm types, production involving multinational enterprises (MNEs) *varies across sectors in a country* (i.e., the share of multinational production in one sector, say biotechnology, differs from the other, say automotive, in a region). Also, it *differs across countries in a sector* (i.e., the share of MNE production in a particular sector differs across regions). As new technologies enter via FDI, there are new varieties partially or totally replacing old types (endogenous obsolescence). Foreign R&D capital stock from countries with higher endowments and a comparative advantage in knowledge-intensive goods affects productivity of host firms. However, productivity gaps across firms (in a nation) and across nations (for a firm) are important characteristics of such spillovers because some firms will be able to absorb the FDI and some will not.

Falvey and Foster-McGregor (2022) discussed that licensing and FDI both matter for boosting exports via enhanced technology flows. Gima *et al.* (2007) showed that for UK manufacturing firms, FDI is a mode of the MNEs to transfer “intangible proprietary assets” for domestic exporters. Baldwin and Robert-Nicoud (2008) showed that with heterogeneities in firms, trade could be pro-growth depending on the costs of innovation adoption, nature of technology and trade in hi-tech goods.

*Heterogeneities across firms* would matter for technology spillover via MNEs and productivity differences. Trade models with firm heterogeneity and product variety based on Melitz (2003) consider micro-level data and evidence that in an industry firms differ in terms of their profitability, qualities, size and performance on domestic and export markets, and hence, response to exogenous shocks. Borin and Mancini (2016) find out the positive effect of FDI on total factor productivity (TFP) and employment of white-collar and blue-collar components of Italian firms. Helpman *et al.* (2004) showed that a small number of MNEs in an economy has a competitive advantage in exporting. The capability of a firm to produce and trade via exporting goods is enhanced by *productive efficiency*. Innovation in the information and communication technology (ICT) sector, causing trade facilitation, has contributed to substantial productive efficiency gains (Bednář, 2019).

These *intra-industry, inter-firm differences* in serving domestic and export markets reflect on aggregate industry productivity. Thus, if there are changes in firm-level technology within an industry/sector, changes in productivity at the macro (aggregate) level could be envisaged. Therefore, linking the changes in firm-level technology at the micro level with those at the macro level in the industry is instrumental for endogenous productivity differences.

*Differences in firm-level absorption of such productivity spillover* – depending on associated factors such as skills, training, institutions, *etc.* – could cause technology and productivity differences across firms affecting their export variety. This endogenizes aggregate productivity in a monopolistically competitive industry via multi-product firms and intra-industry resource reallocation.

Heterogeneity in productivity differences in a multi-product firm can be best explored in a GE framework with intersectoral as well as inter-firm linkages in a model based on input-output data and SAM underlying a CGE framework. Our value addition lies in offering such an analysis in a Melitz-Krugman style CGE setup. CGE models with homogeneous firms and Armington specification have been used to study such technology spillover mechanisms (Das, 2002 and 2015; Li *et al.*, 2018; Dixon *et al.*, 2018). In these models, the setup is with Armington-type product differentiation based on the origin of the product and perfectly competitive market structure where productivity spillover cause divergences driven by inter-regional competition. Therefore, the essence of productivity differences manifest in the firms and the *sources* of such differences are not investigated in those models. Melitz (2003), Eaton and Kortum (2002) and Akgul *et al.* (2016), among others, are points of departure to offer a lens through which micro firm-level interactions as well as macro determinants could be captured. The next section analyses such macroeconomic factors and firm-level characteristics.

## 2.2 Productivity spillovers

Internal organization of firms changes with the change in macroeconomic environment depending on firm-specific factors. They self-select between serving export or domestic markets, or even opt for a combination of both market types. As new technologies enter via FDI, there are new varieties partially or totally replacing old types (endogenous obsolescence; Syverson, 2011). Foreign R&D capital stock from countries with higher endowments, and hence, a comparative advantage in knowledge-intensive goods affects productivity of host firms (Helpman *et al.*, 2004, Yeaple, 2005 and 2009). In the context of 17 transition market economies, Gorodnichenko *et al.* (2014 and 2015) used *firm-level data and national input-output tables* to show that FDI could have positive induced spillover (vertical and horizontal both) in host firms with backward linkages, but not so much with forward linkages (vertical spillover). Gorodnichenko *et al.* (2015) further corroborated their findings in showing the detection of such stronger spillover effects on the firm-level micro data, rather than the weaker effects obtained from linkage variables derived from input-output tables. In an otherwise Melitz-type of structure, Falvey *et al.* (2011) showed that technology gap and

trade barriers jointly determine productivity level and hence, “exogenous technology gap is a key determinant of the size and direction of intra-industry resource allocation introduced by trade” (ibid., p. 17). However, development of the *minimum threshold level of technology absorptive capacity* is crucial for harnessing the benefits. This is more so in the presence of technology transfer because firms’ capabilities to harness new technologies depend on skill intensity differences. A sufficient threshold of human capital contributing to the host sector and nation vis-à-vis that of origin is important for the adoption and catch-up process. It also depends on joint effects of institutional changes and financialization (financial development index or financial inclusion).

Farole and Winkler (2012) studied a cross-section of 25,000 domestic firms in 78 low and middle-income countries to show the role of FDI spillovers (intra- and inter-industry/firm spillovers), domestic absorption capacity and institutional setup in influencing firm productivity. As firms differ in their knowledge capital and input combinations, they are heterogeneous in terms of technology capture and cost asymmetries. These result in quality differentiation or extensive margin reflected in export diversification, as well as in intensive margin. Using a CGE model, Latorre and Yonezawa (2017) analysed the impacts of reductions in tariffs, NTBs and FDI-barriers in the context of the Transatlantic Trade and Investment Partnership (TTIP), showing the beneficial impact for insiders as well as for the USA and the EU. Outsiders except China, Japan and India experienced negative effects. Recently, Hsieh *et al.* (2016) discussed in the context of Canada-US FTA (CUSFTA) that there are “new” gains from trade *in addition to* the traditional gains. Breinlich and Cunat (2016) studied the productivity effects of post-CUSFTA scenarios in heterogeneous firms. Spearot (2016) evaluated the long-run effects of tariff cuts over the period 1994–2000, finding that they benefited 69% of countries, with more beneficial effects for developing nations, whereas post-2000 tariff cuts benefited developed economies.

As vertical spillovers are the strong mode of technology flows, especially due to GVC, regional production networks (RPN) and free trade agreements (FTA), a CGE model based on inter-industry linkages and a social accounting matrix (SAM) is suitable. However, as firm-specific factors matter, we adopt a version of the firm-heterogeneity CGE model augmented via introducing monopolistic competition. Using a CGE model based on the General Equilibrium Modelling Package (GEMPACK), we model, *for the first time*, technology transmission by synthesizing macro-level determinants with micro-level sources of heterogeneity.

### 3. Modelling Productivity Spillovers and Firm Heterogeneity

We consider *two steps of productivity effects*, namely, *changes in thresholds induced* by pure trade and FDI liberalization, and secondly, *pure technology shocks* occurring exogenously but transmitted semi-endogenously to recipients, causing productivity thresholds to change. As technology-intensive manufacturing sectors are sources and clients of technology flows via embodiment of tacit knowledge, we consider heavy machinery as the focused sector, and the ripple effects on other industries.

We first use the GTAP-FDI model to simulate tariff liberalization and reduced restrictions on FDI. Magnitudes of shocks are taken from the literature. The simulation in the GTAP-FDI model yields the effect of tariff liberalization and reduced FDI restrictions on productivity. Depending on numbers of regions ( $r$ ), sectors ( $j$ ) and intermediate sectors ( $i$ ), other traded regions and factors (skilled, unskilled, land, capital and natural resources), the dimensions of the model and its component variables will be enormous, *i.e.*,  $i \times j \times r \times s$ , and go beyond the scope of the paper.

### 3.1 Basics of GTAP model

General equilibrium (GE) models capture economy-wide impacts via changes in the “endogenous” relative prices. A standard assumption of optimizing behaviour forms the basis of consumption and production decisions. The model does not determine absolute price level; rather, it determines the price level relative to a “numeraire” as fixed up in the model. “Domestic” prices are determined from the price equations, input-output relationships and given world prices. The market-clearing equations ensure the equality between demand and supply on both factor and goods markets. The fundamental GTAP model with a schematic diagram is shown in Figure 1. Each region has a representative regional household. In this model, “saving” enters the regional household’s per capita utility function as a “commodity”. Thus, in the closure of the GTAP model, the representative household collects the entire income produced in the economy and distributes it over saving, private household expenditures and government expenditures (final demand in the extant model). Like the other two components, maximization of per capita utility function subject to income yields the demand for “saving” endogenously. We conceive of this as a “real” quantity such as “units” of commodities.

A global bank assembles a portfolio of regional saving (both private and government) for a global saving pool and aggregate to form a composite homogeneous good. A price (PSAVE) is set by the global bank as a Walrasian auctioneer. If all firms earn zero profit, all other markets are in equilibrium, and the households are on their budget constraints, then the market for this “saving” commodity will automatically clear following Walras’s Law, guaranteeing equilibrium. Regional demand for this “saving” commodity is generated by the demand for capital formation and “saving” is mobilized for circulation as investment through capital creation, providing investible funds. The global bank distributes this composite investible “fund” to the “savers” (price-takers). PSAVE is a weighted average of the price of each region’s capital goods obtained from the zero pure-profit condition. Although different regions have different “shares” in the global “saving” pool, the model does not have any mechanism incorporating ownership of capital, shares allocation and dividends in this basket; see Hertel (1996) and (Das 2014b) for details.<sup>2</sup> We use the GTAP Version 9 database and a modified non-linear CGE model with detailed sectoral and regional

2 See <https://www.gtap.agecon.purdue.edu/models/default.asp> as the publicly available source of this figure.

specifications based on micro foundations (Aguilar *et al.*, 2016). The production technology tree is a *nested* one for combining into composites. The inputs are a composite of labour, land and capital. Intermediate input is a composite of foreign and domestic intermediate. At the top level, the output  $Y_r$  is produced in the region  $r$  via a Leontief fixed-coefficient technology using intermediates  $Q_r$  and a primary input (labour, capital, land) CES composite  $Q^V_r$ .  $Q_r$  is the intermediate input demand for the Armington composite by any region  $r$ . Each  $Q_r$  is produced in a CES production nest using domestic goods and a composite of foreign goods distinguished by country of origin. For notational convenience, in  $Q_{rs}$  the first subscript refers to the using region and the second one refers to the foreign source.  $Q^F_r$  is produced in the region  $r$  using the goods imported from other regions, say,  $s$  and  $t$ . Let  $Q_{rs}$  and  $Q_{rt}$  be respectively the intermediate input demand for commodities from  $s$  and  $t$  by using the region  $r$ . The CES production function for the intermediate input nest is:

$$Q^F_r = A^F_r \{ \delta^F_r \} (Q_{rs})^{-\beta_{rF}} + (1 - \delta^F_r) (Q_{rt})^{-\beta_{rF}} \}^{-1/\beta_{rF}} \quad (1a)$$

where  $\delta^D_r$  is the distribution parameter,  $\beta_r$  is the substitution parameter and the substitution elasticity between domestic and foreign products is  $[1/(1 + \beta_r)]$ .

The primary factor composite  $Q^V_r$  combines the primary factors of land ( $T$ ), labour ( $L$ ) and capital ( $K$ ) via CES:

$$Q^V_r = A^V_r \left\{ \sum_f \delta^V_{rf} (Q^f_r)^{-\rho_r} \right\}^{-1/\rho_r} \quad (2)$$

$Q_r$  and  $Q^V_r$  are combined via fixed-proportion technology. However, there is scope for substitution between domestic and imported varieties of composite goods, as there is between  $L$ ,  $K$  and  $T$ . At the top level the (Leontief) production function is:

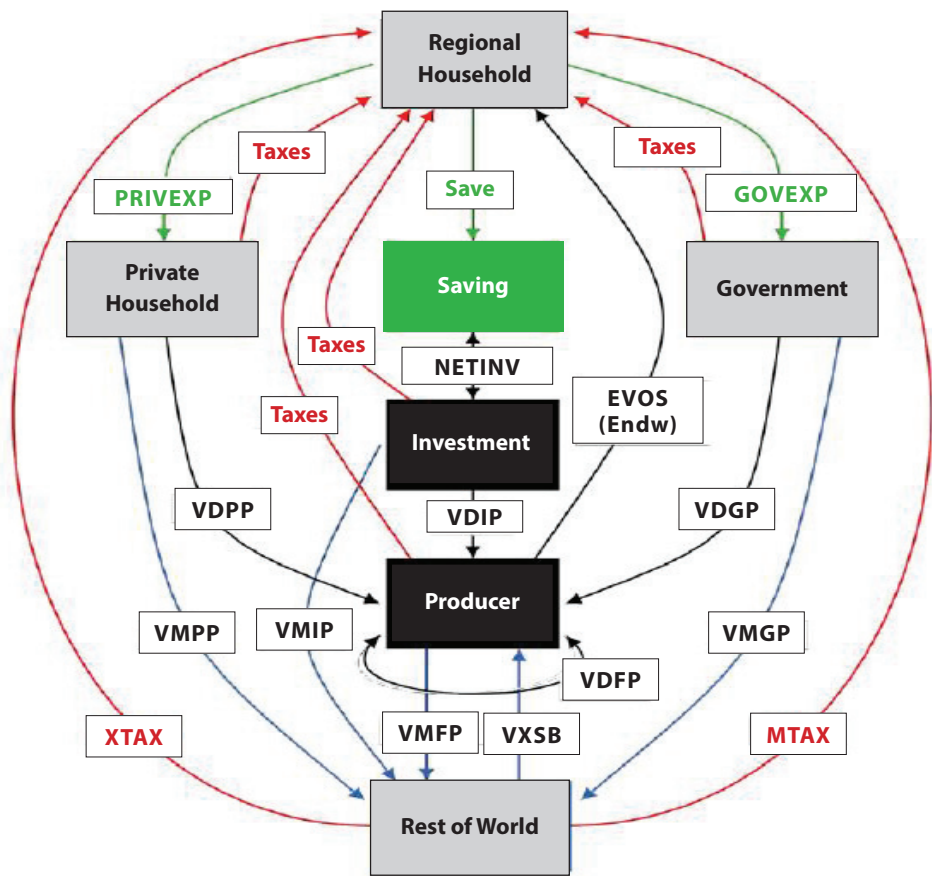
$$Y_r = [AO]_r \min \{ A^O_r Q_r Q^V_r \} \quad (3)$$

where  $Y_r$  is the GDP (production) and  $[AO]_r$  is the Hicks-neutral technical progress (HNTF) or TFP changes.  $A^F_r$  and  $A^V_r$  are HNTF parameters. We consider TFP or HNTF parameters outside the CES nest (Figure 2). These HNTFs apply to the composite outer nest (Hanoch, 1971). The GEMPACK software suite developed at the Centre of Policy Studies, Monash University, Australia is used for the simulations. The *technical shifter variable* [namely,  $ao(i, r)$ ] in the GTAP-FDI model is made endogenous in the closure. Subsequently, we use the productivity changes generated in the simulation as an input to the GTAP-HET model for generating the percentage change in the productivity.

Given our plans to link the GTAP-FDI and the GTAP-HET to incorporate FDI liberalization mechanism,  $ao(i, r)$  is endogenized in the FDI model and subsequently injected as an exogenous shock component of the same variables in the second step, where productivity changes are results of the tariff liberalization and FDI flows in the prior simulation. The number of firms on the domestic and foreign markets is now determined via the cut-off productivity threshold below which some cease to exist. A “shape parameter” – inverse measure of productivity and heterogeneity of firms – influence the firms’ “productivity draw” from their productivity distribution. With

increase in the value of *SHAPE*  $\gamma(i)$ , firms’ productivity becomes uniform, so that they are more homogeneous in industrial composition. With a fixed number of firms, some quit in the long-run closure, which endogenously determines the firm and industry productivity and their shares in local and world markets.

Figure 1: Standard GTAP model and parameters



Agents

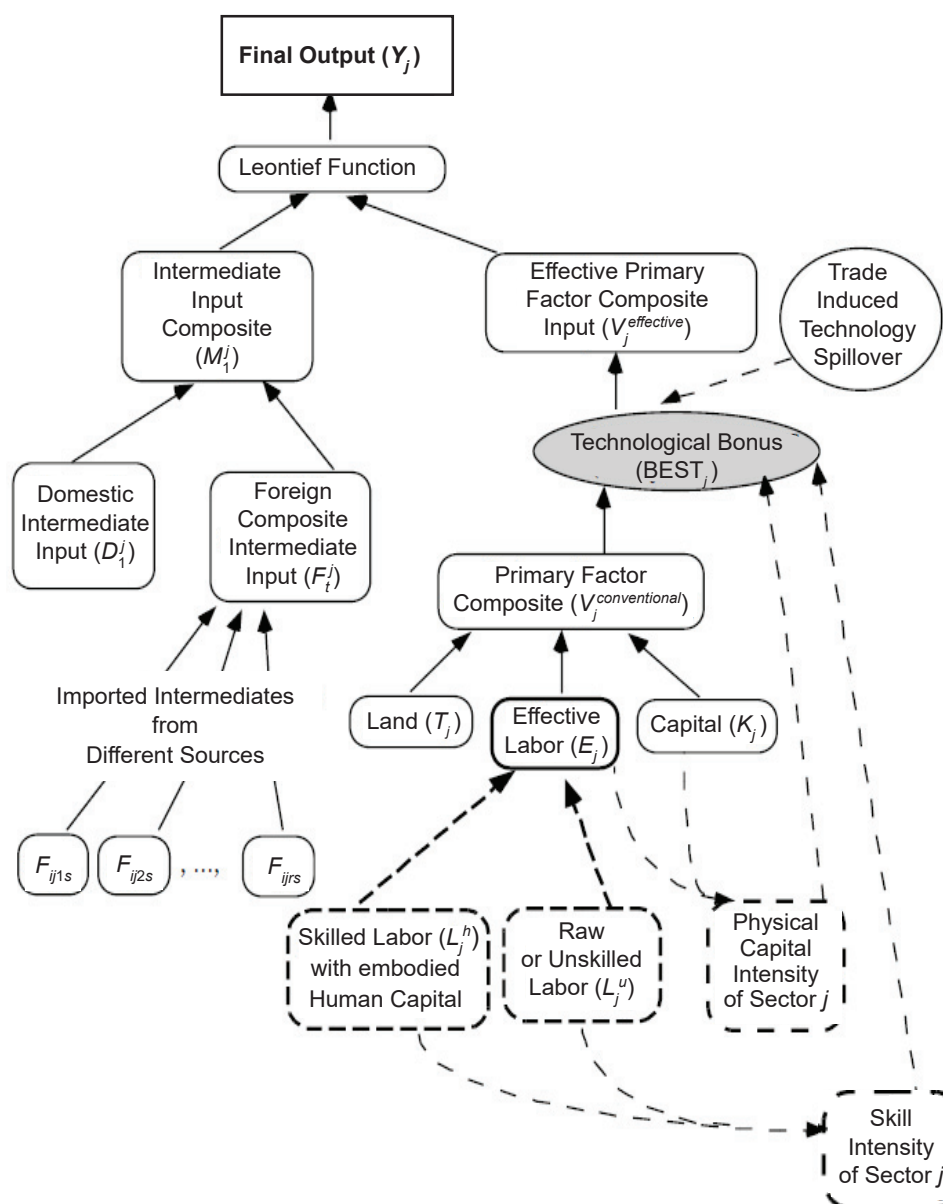
Households, Firms, Government, Investment

- VDPP domestic purchases, by households, at producer prices
- VDFP domestic purchases, by firms, at producer prices
- VDGP domestic purchases, by government, at producer prices
- VDIP domestic purchases, by investment, at producer prices

Key Parameters

- ESBD Armington CES domestic / imported allocation
- ESBM Armington CES for regional allocation of imports
- ESBT CES between primary factors and intremediate inputs
- ESBV CES between primary factors in production
- ETRE CET between sectors for sluggish primary factors
- INCP CDE expansion parameter
- SUBP CDE substitution parameter

Source: Corong, E., Hertel, T., McDougall, R., Tsigas, M., and van der Mensbrugghe, D. (2017). The Standard GTAP Model, Version 7. Journal of Global Economic Analysis, 2(1), 1–119. doi: <https://dx.doi.org/10.21642/JGEA.020101AF> Accessed at: <https://www.gtap.agecon.purdue.edu/resources/download/9143.pdf>

**Figure 2: Production technology structure in GTAP model based on Das (2019)**

Source: Das, Gouranga G. (2019)

### 3.2 GTAP-FDI model

Ciuriak *et al.* (2015 and 2017) explored quantitative effects of the TPP and CPTPP in an applied theoretical framework using firm-based new trade theory. However, as the GTAP-HET, GTAP-FDI and all GTAP-based models originate from the GTAP framework as the fundamental paradigm, its widespread application is quite well-known in the public domain for replication in separate contexts. As mentioned before, it comprises of domestic and foreign investors for each sector and region. We disaggregate the original GTAP investment-related variables by constructing the following matrices: gross operating surplus  $GOS(j, r)$ , rates of return  $ROR(j, r)$ , depreciation rate  $D(j, r)$  and growth rates of capital stocks  $K\_Gk(j, r)$ . The  $GOS$  matrix for 2011 is the same as the value of for-

eign intermediate capital ( $VFM(Capital, j, r)$ ) in the GTAP 9 database. The data for  $ROR$ , depreciation and growth of the capital stock are obtained from company-specific data, based on capital.

The other data sources we rely on include the foreign affiliate sales (FAS) matrix, the FDI stock matrix, and the FDI restrictiveness index based on UNCTAD and OECD data on FDI restrictiveness (see Fukui and Lakatos, 2012; Lakatos and Fukui, 2014). Dividing the FAS by total domestic sales of products generates the penetration rates of foreign firms. FAS data provide better information about the operations of foreign affiliates. We assume the same depreciation rate for firms owned by domestic and foreign investors.

The concept of a *phantom tax* is introduced to break down the regional gross operating surplus into gross operating surplus for domestic and foreign-owned capital. The objective is that phantom tax controls enter FDI without collection of revenue, even though foreign capital has higher returns. With the removal of the phantom tax in a policy shock, foreign capital has an incentive to take advantage of the higher returns by increasing investment, thus resulting in expansion of the FDI stock.

We quantify the effect of the restrictions on FDI to determine by how much the share of FDI in the region-sector capital stock would increase if we removed all barriers, and we use these results to estimate the phantom tax applying to FDI in each region and sector. The phantom tax creates a wedge between the  $ROR$  of domestic versus foreign-owned capital; this allows us to derive the gross operating surplus (GOS) in a gravity-like econometric specification.

In the model, we derive the expression linking a change in the level of the phantom tax ( $\tau_{row}$ ) to a change in FDI, consistent with the calculation where the change in FDI was linked to a change in the FDI restrictiveness index. As opposed to this, another model in the MONASH investment function, the growth rate of capital (and hence the level of investment) is determined by investors' willingness to supply increased capital to the industry  $j$  in the region  $r$  ( $K\_G(j, r)$ ). That depends on changes in the expected  $ROR$  for capital. Thus, following the MONASH model, we assume that investors are willing to support capital growth in the industry  $j$  in the region  $r$  in the year  $t$  to move above the historically normal rate of capital growth for this sector-region only if they expect the  $ROR$  to be above the historically normal level.

### 3.3 Firm heterogeneity model (GTAP-HET)

Even though productivity change is endogenously determined by compositional changes in the GTAP-HET model, an exogenous variable causes productivity changes. This is trade-induced as in the Melitz model, where tariff liberalization leads more productive firms to penetrate export markets while less productive firms contract or exit, resulting in an increase in the industry's overall productivity. The overall productivity change in the GTAP-HET model corresponds to the variable  $ao(i, r)$ . On the other hand, the exogenous part of the productivity change allows for exogenous shocks to productivity such as the isolated effect of FDI on productivity. The exogenous productivity shock is required in our simulation as the GTAP-HET model does not incorporate

the FDI mechanisms. In our version of the GTAP-HET model augmented with technology diffusion, we link the productivity spillovers *at two levels: level 1 (aggregate or macro level) and level 2 (micro firm level)* where inter-firm as well as inter-sectoral linkages contribute to spillovers (Figure 3). Technological change in the sources induces endogenous productivity spillovers to destinations via intermediates. Such technological innovation entails productivity escalation in user sectors such as agricultural, manufacturing, food, *etc.* In the GTAP-HET, the endogenous shock component causing productivity thresholds to change could alter thanks to: (i) trade policy shocks (*e.g.*, tariff cuts) and (ii) productivity spillovers. There are both price and cost responses to trade liberalization, at intensive margin (of surviving firms) and entry-exit (extensive margin). Even without any explicit mechanisms of such technology flows across donor-recipient pairs, we consider the extant equations and relevant  $ao(i, r)$  pairs. In the GTAP-HET model, trade-induced changes in productivity thresholds to enter markets, denoted as  $aost(i, r, s)$ , result in changes in overall industry productivity, reflected in changes in  $ao(i, r)$ . A tech shock in the host nation will cause changes in domestic *sunk* and other costs; however, for trade-induced shocks, changes in the source region will cause changes in destination regions via the  $r-s$  bilateral linkages. In the GTAP-HET, change in  $aodf(ir)$  and  $aods(ir)$  causes change in  $ao(ir)$ ; change in  $aoxf(irs)$  and  $aoxs(irs)$  also causes change in  $ao(ir)$ . Those shock transmission will cause ensuing changes in  $avafxall$ ,  $avafx$ ,  $avafd$ , *etc.*, and  $n(ir)$ .

We run simulations in **two cases**:

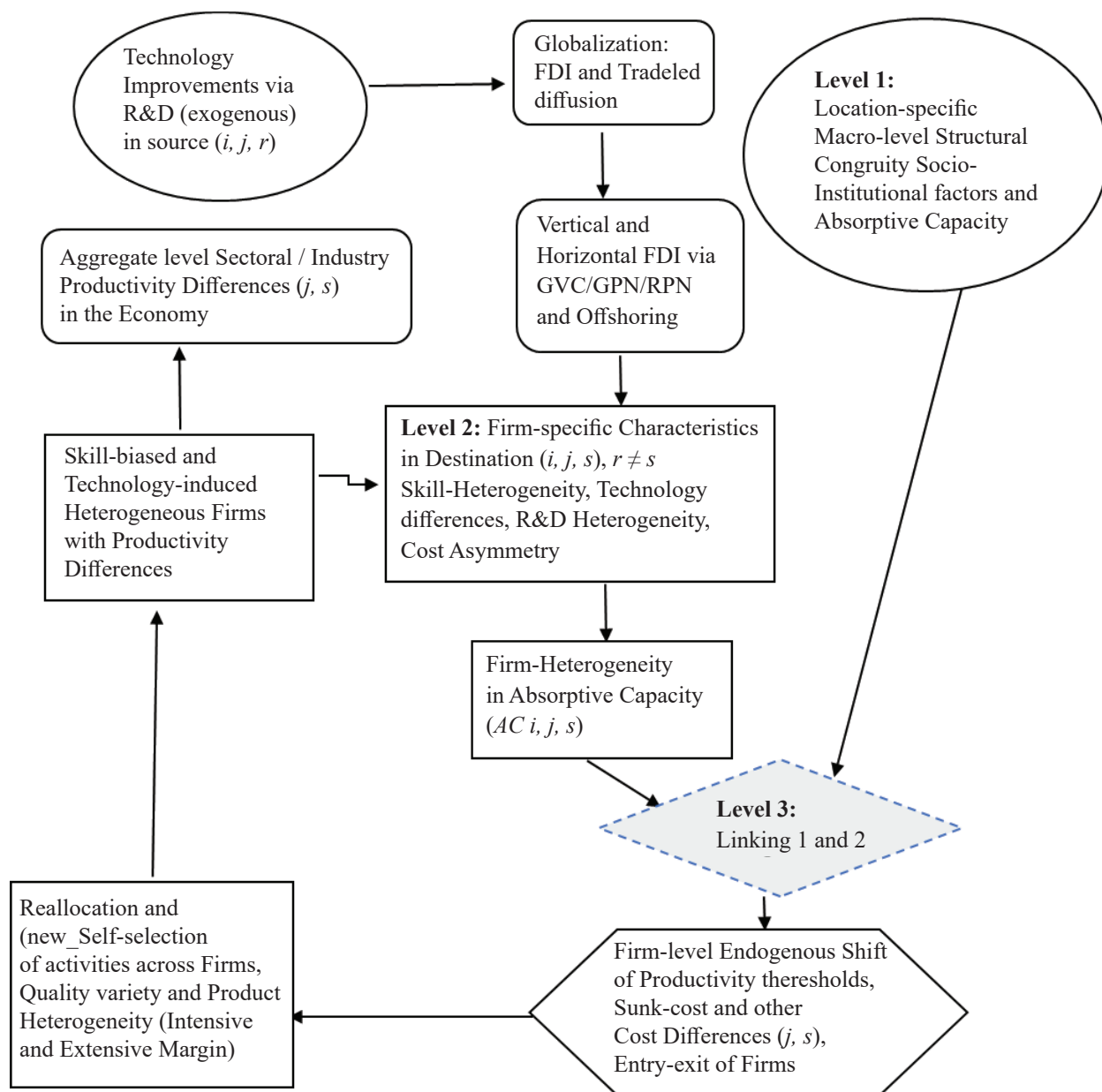
**(a): Productivity threshold change** on domestic and export markets causing average productivity to change on respective markets and for the whole industry. Shocks in fixed set-up costs,  $avafe(ir) > 0$ , result in a change in the productivity threshold  $aost(i, r, s)$ . Similarly, shocks in fixed trading costs  $avafs(i, r, s)$  change the productivity threshold and endogenous changes in  $ao(ir)$  in regions ( $r$ ) and sectors ( $i$ ). Hence:

$$\begin{aligned} ao(j, r) = & SHRSMD(j, r, r) * aos(j, r, r) \\ & + \text{sum}(s, \text{REG}, [1 - \text{DELTA}(r, s)] \times SHRSMD(j, r, s) \times aos(j, r, s)) \\ & + [\text{MARKUP}(j, r) - 1] \times \text{sum}(s, \text{REG}, SHRSMD(j, r, s) \times [ns(j, r, s) - nt(j, r)]) \\ & + aosec(j) + aoreg(r) + aoall(j, r) \end{aligned}$$

**(b): Productivity transmission in GTAP-HET:**

$$qo(ir) = qvav(ir) + avav(ir) + ao(ir).$$

Here, trade-induced technology shocks occur via imported intermediates used in final goods production (VIFM). ICT (general-purpose technology) causes productivity improvements via trade and FDI in the destination ( $s$ );  $ao(i, r)$  in the source of technical change causes endogenous changes in  $ao(j, s)$ , where  $i \neq j$ ,  $r \neq s$ . Moreover,  $ao(j, s)$  is linked to  $ao(ir)$  via the following:  $ao(j, s) = F[\cdot] ao(ir)$ .  $F[\cdot]$  determines intermediate input intensity at the average firm/industry level.

**Figure 3: Principal pathways for productivity transmission in augmented GTAP**

Source: Authors' construction for showing theoretical mechanism

**Equation**  $Q_{GDP\_r}$  # GDP quantity index # (all,r,REG)  $GDP(r) \times q_{gdp}(r)$

$$\begin{aligned}
 &= \text{sum}(i, \text{TRAD\_COMM}, \text{VGA}(i, r) \times q_g(i, r)) + \text{sum}(i, \text{TRAD\_COMM}, \text{VPA}(i, r) \times q_p(i, r)) \\
 &+ \text{REGINV}(r) \times q_{cgds}(r) + \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \text{VSWD}(i, r, s) \times q_s(i, r, s))) \\
 &+ \text{sum}(m, \text{MARG\_COMM}, \text{VST}(m, r) \times q_{st}(m, r)) \\
 &- \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \text{VDWS}(i, s, r) \times q_s(i, s, r)));
 \end{aligned}$$

TFP effect is measured by the key equation in GTAP's Tablo-generated program (TABMATE) GEMPACK language.<sup>3</sup> The above is an illustration of GEMPACK code program.<sup>4</sup>

## 4. Simulation Scenarios

We consider broadly *two kinds* of shocks/simulations: technology shocks and their propagation via traded intermediates, and vertical FDI. Exogenous technological improvements in MNC plants in developed economies (*e.g.*, sources such as the USA, EU and Japan) on firm sites in destinations abroad affect technical efficiency gains. We capture the transmission from the rise in FDI inflows owing to the TPP causing productivity spillovers in the dynamic GTAP-FDI model. The role of mega-trade deals in altering production structures in the context of the TPP follows. Consider *two generic technological advances and their transmission*: (i) Aggregate industry-level intersectoral spillover. Aggregate change at the source is endogenously brought about by firm-level technical change occurring for changes in fixed entry costs for either or both domestic and international markets but confined only to firm level. (ii) Firm-to-firm technology flows affecting aggregate productivity  $i$  from the source  $i$  in the region  $r$ . While diffusing at the host, it affects the threshold with endogenous firm productivity at recipients.

## 5. Database and Simulation Results: Macroeconomic, Industry and Firm-level Effects

Despite uncertainties surrounding implementation of the TPP, our database will reflect on TPP-based adjustments using the GTAP 9 database (Aguiar *et al.*, 2016); see Table 1. The first step in our simulations was to understand the effect of reduction of tariffs in the TPP on FDI flows and their consequent effects on productivity. Figure 4 shows the productivity spillovers from FDI flows created by the TPP. Given that the tariffs are most prominent in agriculture, we see the biggest productivity effects in that sector, followed by extraction, light manufacturing sectors such as textiles and others, particularly in Mexico.

3 See footnote 4 for clarification of the terms in this example of software codes of equations.

4 The equation above is a software replica of equations. We do not elaborate on those for the sake of parsimony. One can check this on the GTAP website or readers can contact the authors.

**Table 1: Sectoral and regional aggregations adopted for simulation**

| Regions and elements |                                                                                                                                                                                                                                                                       | Sectors and descriptions |                                                                             |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-----------------------------------------------------------------------------|
| <b>Rest of TPP</b>   | Australia, New Zealand, Japan, Brunei, Peru, Malaysia, Singapore, Vietnam, Chile                                                                                                                                                                                      | <b>Agriculture</b>       | Grains and crops, sugarcane, oilseeds, fibres, animal products, <i>etc.</i> |
| <b>Canada</b>        |                                                                                                                                                                                                                                                                       | <b>Extraction</b>        | Mining and extraction                                                       |
| <b>USA</b>           |                                                                                                                                                                                                                                                                       | <b>TextWapp</b>          | Textiles, apparel and clothing                                              |
| <b>Mexico</b>        |                                                                                                                                                                                                                                                                       | <b>LightMnfc</b>         | Light manufacturing                                                         |
| <b>China</b>         |                                                                                                                                                                                                                                                                       | <b>HeavyMnfc</b>         | Heavy manufacturing, electronics, ICT                                       |
| <b>EU-28</b>         | European Union members: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, UK, Bulgaria, Croatia | <b>Services</b>          | Other services                                                              |
| <b>ROW</b>           | Rest of the world                                                                                                                                                                                                                                                     |                          |                                                                             |

Source: Authors' compilations for implementation based on GTAP database V.9

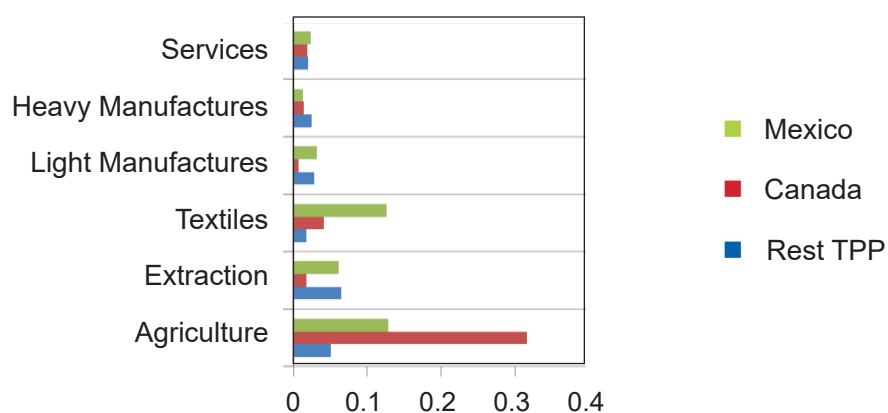
Canada faces rather moderate increases in productivity (See Table 2 and the figures).

**Table 2: Productivity improvements following the shock (post-simulation)**

| GTAP sector with ID | USA    | Canada | Mexico | China  | ROTPP | RoW    | EU-28    |
|---------------------|--------|--------|--------|--------|-------|--------|----------|
| 27 Textiles_d       | 0.03   | 0.038  | 0.061  | 0      | 0.029 | −0.161 | 0.005333 |
| 28 WearAppri_d      | 0.009  | 0.045  | 0.171  | 0.001  | 0.006 | −0.203 | 0.006611 |
| 29 LeatherPr_d      | 0.04   | 0.015  | 0.217  | 0.001  | 0.04  | −0.181 | 0.009056 |
| 30 WoodProdu_d      | 0.002  | 0.007  | 0.024  | −0.001 | 0     | −0.034 | 0.008722 |
| 31 PaperProd_d      | 0.001  | 0.003  | 0.006  | 0      | 0.008 | −0.014 | 0.006167 |
| 32 PetroCoal_d      | 0.024  | 0.011  | 0.005  | −0.001 | 0.019 | −0.089 | 0.011389 |
| 33 ChemicalIR_d     | 0.004  | 0.011  | 0.009  | −0.001 | 0.021 | −0.033 | 0.012556 |
| 34 MineralPr_d      | 0      | 0.008  | 0.009  | −0.001 | 0.016 | −0.046 | 0.013611 |
| 35 FerrousMe_d      | −0.004 | 0.008  | 0.01   | −0.002 | 0.005 | −0.019 | 0.019056 |
| 36 MetalsNec_d      | −0.001 | 0.044  | 0.054  | −0.003 | 0.046 | −0.077 | 0.002833 |
| 37 MetalProd_d      | 0.002  | 0.007  | 0.012  | −0.003 | 0.005 | −0.033 | 0.012944 |
| 38 MotorVehi_d      | 0.023  | 0.003  | 0.032  | −0.002 | 0.043 | 0.026  | 0.045778 |
| 39 TrnsprtEq_d      | 0.003  | 0.001  | 0.014  | −0.002 | 0.093 | −0.06  | 0.013556 |
| 40 ElectrEq_d       | −0.036 | 0.01   | 0.01   | −0.001 | 0.044 | −0.038 | −0.02967 |
| 41 MachnryEq_d      | −0.005 | 0.008  | 0.012  | −0.001 | 0.021 | −0.046 | 0.007389 |
| 42 ManfctNec_d      | 0.005  | 0.048  | 0.007  | −0.001 | 0.011 | −0.051 | 0.012389 |
| 43 Electrici_d      | 0.007  | 0.001  | 0.009  | −0.002 | 0.013 | −0.035 | 0.006667 |
| 46 Construct_d      | 0.006  | 0.026  | 0.068  | 0      | 0.034 | −0.064 | 0.006056 |
| 47 Trade_d          | 0.004  | 0.02   | 0.017  | 0.001  | 0.015 | −0.033 | 0.002111 |

Source: Authors' simulation results from GTAP-FDI and GTAP-HET models

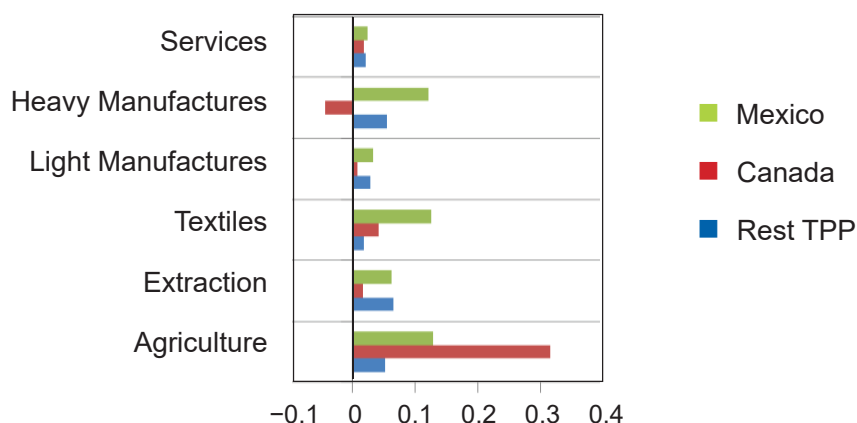
**Figure 4: Productivity spillovers from FDI created by TPP (from GTAP-FDI model)**



Source: Based on authors' simulation results from GTAP-FDI model

Figure 5 shows the results of the GTAP-HET model, where we implemented the above shocks, in addition to the TPP tariff reduction shocks. These results are more prominent than what we noted in Figure 1 because of FDI. Two reasons underlie the decline in TFP for Canadian heavy manufacturing: firstly, the productivity effect of FDI in this sector is low; secondly, the compositional effects of tariff reduction meant a reduction in productivity in this sector in Canada, due to an increase in less productive firms in proportion to highly productive firms.

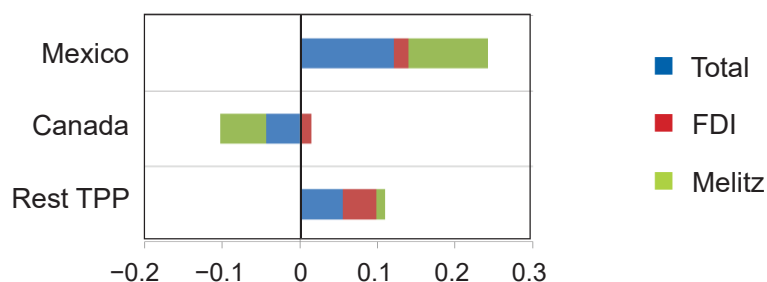
**Figure 5: Productivity effects of compositional changes (from GTAP-HET model)**



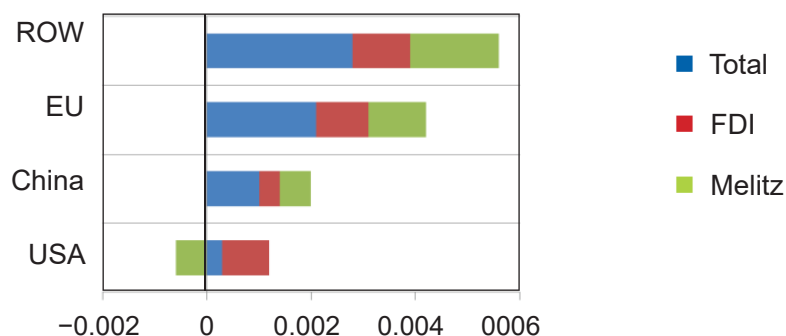
Source: Based on authors' simulation results from GTAP-FDI model

Figure 6 digs deeper into the heavy manufacturing sector since it has seen a negative effect in productivity. We observe that all the negative effect in Canada came from the compositional effect, which means that the fraction of heavy manufacturing firms that are less productive increases due to trade opening up. The small positive effect from FDI productivity spillovers is not sufficient to offset the larger negative compositional effect (Melitz effect). For Mexico and the rest of the TPP (10 countries), the positive effects dominate both compositional and FDI productivity spillovers. Figure 7 shows the impact on non-TPP members. All of them except the USA gain due to both positive FDI and compositional productivity effects. The USA loses in terms of compositional effects, despite gaining in FDI spillovers.

**Figure 6: Productivity decomposition for TPP members in heavy manufacturing sector**

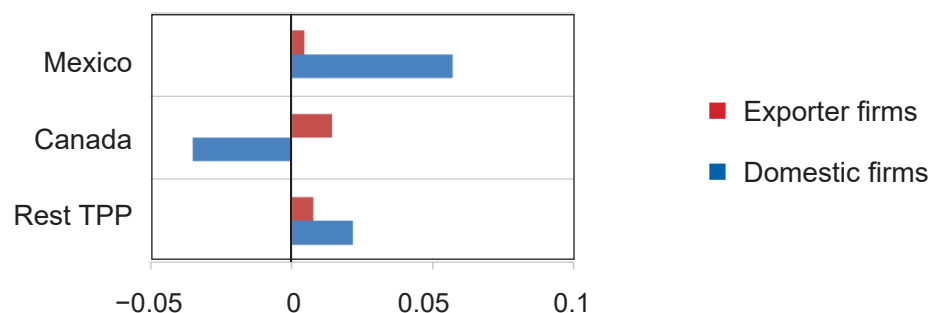


Source: Based on authors' simulation results from GTAP-FDI and GTAP-HET models

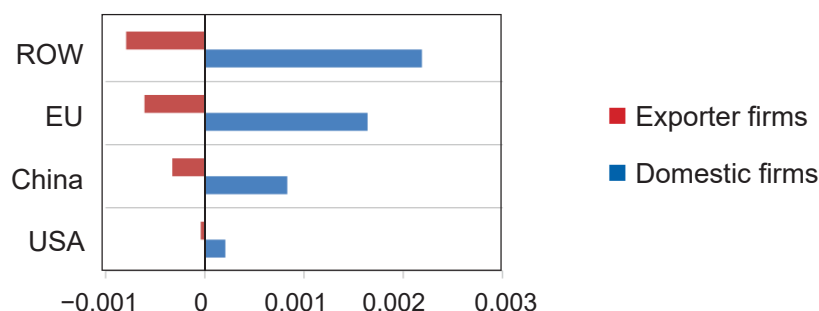
**Figure 7: Productivity decomposition for non-TPP members in heavy manufacturing**

Source: Based on authors' simulation results from GTAP-FDI model

Figure 8 further decomposes the compositional effects of the change in share-weighted average productivity into exporting and domestic firms. With trade, exporters across the TPP countries gain in productivity; however, Canadian domestic firms lose. These are purely compositional changes. For TPP countries, the average productivity of exporters increases slightly since firms with lower productivities exit the export markets, while relatively productive firms expand or pick up. The productivity increase in domestic firms is relatively higher than the exporters' increase. This is mostly because the domestic firms have a higher weight with home market bias. Unlike other TPP countries, Canada experiences a decline in average productivity for domestic firms because productive firms on Canada's domestic market exit. Even highly productive firms lack in acquiring competitiveness against cheaper imports from Rest of TPP and Mexico. Producer prices in Canada increase, while those in Mexico and Rest of TPP decrease as shown in Figure 10. Hence, Canadian domestic firms lose competitiveness against TPP countries. In non-TPP countries (Figure 9), there is a clear story: domestic firms increase their productivity while exporters face a decline in productivity. The USA experiences the least effects on both sides.

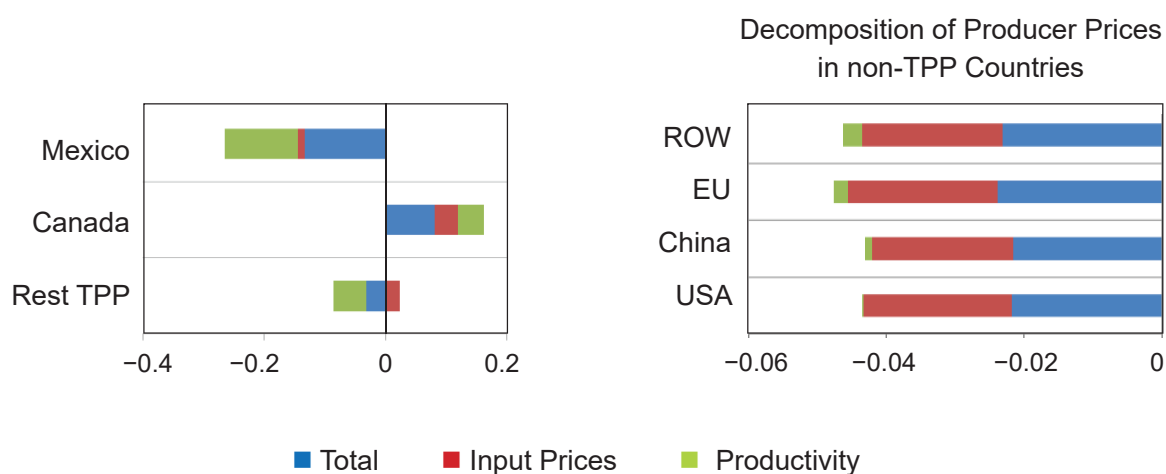
**Figure 8: Productivity effects in heavy manufacturers in TPP countries: Domestic and exporting firms**

Source: Based on authors' simulation results from GTAPHET model

**Figure 9: Productivity effects in heavy manufacturers in non-TPP regions: Domestic and exporting firms**

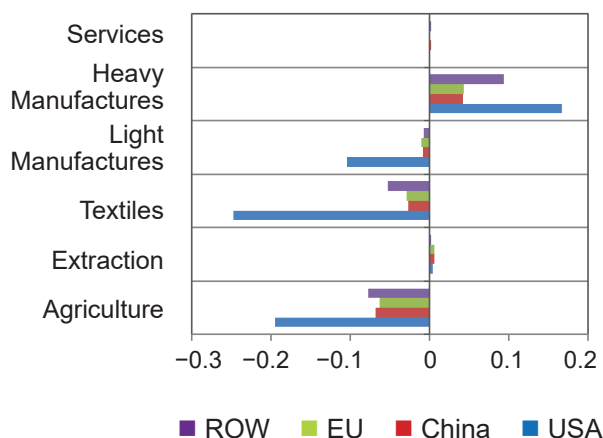
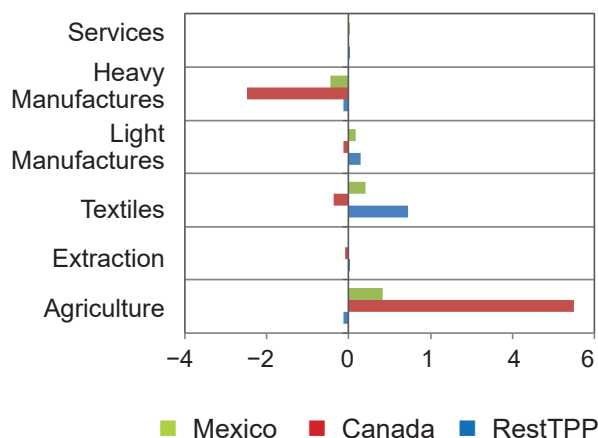
Source: Based on authors' simulation results from GTAP-HET model

As Figure 10 shows, prices increase in Canada due to the decline in productivity and rise in input prices, while Mexico sees a fall in prices due to greater productivity and lower input prices. Other TPP members also face a rise in input prices, but the productivity effects are enough to outweigh them and result in overall reduction in prices.

**Figure 10: Producer prices and their decomposition in heavy manufacturing**

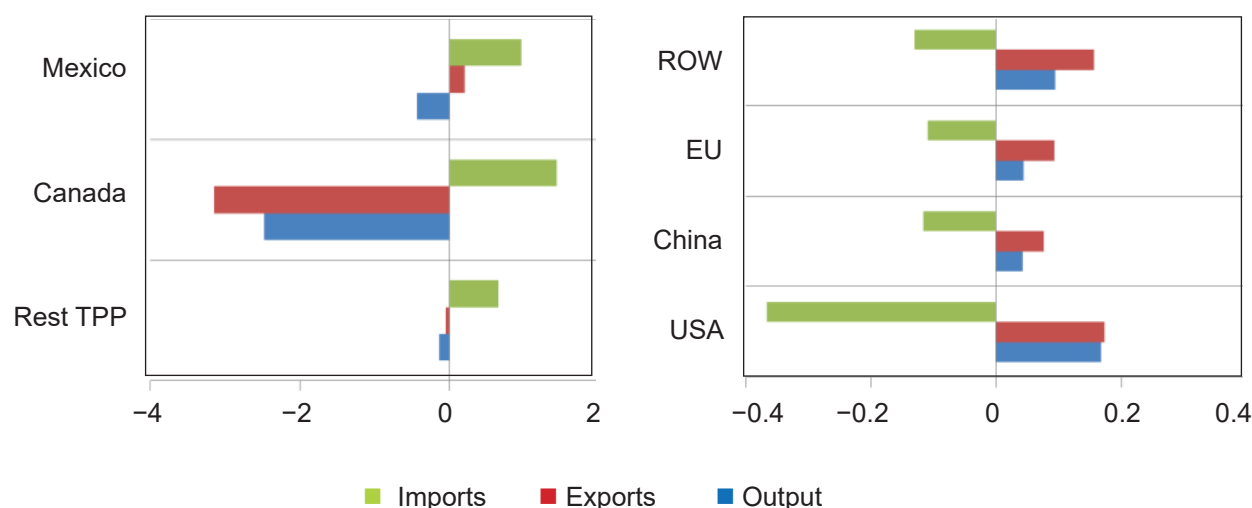
Source: Based on authors' simulation results from GTAP-FDI and GTAHP-HET models

Non-TPP members show a marginal decline in prices. The reason for the rise in input prices in all TPP countries except Mexico is their increased demand due to opening of trade in general. The price rise in Canada and other TPP members except Mexico is accompanied by output reduction in the heavy manufacturing sector as seen in Figure 11; however, output expands in all other sectors; in non-TPP members, it is the other way around: heavy manufacturing output expands, while others contract.

**Figure 11: Output effects in TPP countries****Change in Output effects in non-TPP countries****Change in Output effects in TPP countries**

Source: Based on authors' simulation results from GTAP-HET model

Although it is unusual that the trade-liberalizing countries lose in terms of output in a sector at the cost of the non-participating countries, Figure 12 sheds light on this aspect by showing the changes in import, export and output together.

**Figure 12: Heavy manufacturing effects in TPP and non-TPP countries**

Source: Based on authors' simulation results from GTAP-FDI and GTAP-HET models

**Table 3: Percentage change in exports and imports in post-simulation phase**

| qxw           | Exports   |          |       |          |         |         |
|---------------|-----------|----------|-------|----------|---------|---------|
| R024          | 1 RestTPP | 2 Canada | 3 USA | 4 Mexico | 5 China | 6 EU-28 |
| 1 Agriculture | 1.99      | 16.10    | −1.13 | 6.88     | −1.44   | −0.62   |
| 2 Extraction  | 0.18      | 1.20     | −0.61 | 0.42     | −0.13   | −0.10   |
| 3 TextWapp    | 4.90      | 2.40     | −2.39 | 3.67     | −0.07   | −0.21   |
| 4 LightMnfc   | 1.32      | 0.15     | −0.58 | 0.82     | −0.07   | −0.05   |
| 5 HeavyMnfc   | −0.05     | −3.15    | 0.17  | 0.20     | 0.08    | 0.09    |
| 6 Services    | −0.15     | −0.06    | 0.04  | −0.27    | 0.05    | 0.06    |
| qiw           | Imports   |          |       |          |         |         |
| R026          | 1 RestTPP | 2 Canada | 3 USA | 4 Mexico | 5 China | 6 EU-28 |
| 1 Agriculture | 3.19      | 2.42     | 0.05  | 1.85     | 0.02    | 0.04    |
| 2 Extraction  | −0.18     | −2.27    | 0.22  | −0.03    | 0.06    | 0.03    |
| 3 TextWapp    | 0.59      | 1.19     | 0.02  | 2.02     | −0.03   | −0.01   |
| 4 LightMnfc   | 0.39      | 0.45     | −0.02 | 0.90     | −0.02   | −0.02   |
| 5 HeavyMnfc   | 0.65      | 1.43     | −0.37 | 0.96     | −0.12   | −0.11   |
| 6 Services    | 0.15      | −0.03    | −0.01 | 0.16     | −0.02   | −0.03   |

Source: Authors' simulation results from GTAP-FDI and GTAP-HET

In short, trade liberalization increases imports, which, coupled with a lack of exports arising from a lack of competitiveness, results in an output reduction in TPP members. In the non-TPP member countries, as shown in Figure 12, imports fall and exports rise slightly, but enough to keep the output slightly higher (Table 3 and Figure 12).

## 6. Policy Insights and Conclusion

Proliferation of regional trade agreements (RTAs) under modern trade agreements entails potential productivity benefits as a regional agreement has scope beyond tariffs and non-tariff barriers (NTBs). With a large amount of FDI flows, trade in services, GVCs and offshoring, we studied

the impact across the economies by linking the GTAP-FDI model with the GTAP-HET model. We offered illustrative simulations for productivity spillovers via trade and FDI liberalization under TPP, consisting of cutting down of tariffs, non-tariff barriers and removal of barriers to FDI. The exercise threw light on firm-level impact of trade FDI-linked spillover under alternative regional trade agreements, such as the RCEP or TTIP, or other FTAs. This has relevance for FTAs in EU members and non-members for productivity spillovers through regional cooperation.

We find that the FDI productivity spillover effect is smaller than the Melitz composition effect, though the former is always positive while the latter is negative for heavy manufacturing in Canada. This is due to the exit of productive firms in this country. The overall rise in input demand results in an increase in their prices, thereby raising the prices of heavy manufacturing, and consequently, lower output in this sector in TPP countries. As a result, TPP countries may import more, export less and hence produce less in heavy manufacturing. In all other sectors, trade liberalization promotes output growth just as expected. In non-TPP members, there is a tendency to take up the slack created by lower production of heavy manufacturing by TPP members, but these countries lose in all other sectors. The FDI liberalization component would have a larger impact as it leads to productivity benefits on top of the trade-induced benefits via forward and backward linkages. Also, those outside such multilateral regional trade agreements do not benefit much. To make the *TPP inclusive*, the third-country discriminating rules and standards need to be eliminated for better multilateral cooperation.

People differ in terms of understanding how trade and FDI policy jointly work to elicit gains from trade. Overall positive allocative and technical efficiency gains are prominent due to heterogeneous firms' exposure to the global market. The policy implication arising from this study is that there is a need for investments in productivity improvements in sectors such as heavy manufacturing and machinery, which are skill and technology-intensive, and those which lack the productivity improvements can gain from trade-induced growth. Our "what if" simulation analysis using an innovative joint mechanism via FDI and firm-heterogeneity shows that liberalization tends to positively influence FDI by increasing market access and inducing vertical coordination among members of proposed FTA schemes. Trade creation and FDI-boosting effects in the members are important policy dimensions highlighting the fact that dismantling of trade barriers could attract more FDI and, in turn, generate more spillover effects furthering incentives for foreign investment. Although India and the USA have opted out, pursuit of the TPP would stand in good stead in the long run via accelerating economic activity. Also, an increase in the threshold level of firm productivity – via novel technology transmission – will enhance product diversification. Thus, trade and FDI policy should be viewed coherently in an integrated policy space generating positive externalities. The results have a bearing on other regional integration such as in the EU and non-EU members and implications for Central European countries for regional productivity convergence or spillover benefits.

Future extensions may include change in absorptive capacity-threshold via changes in skills along with changes in institutions via IPR and location-specific innovation policies. As sources of productivity differences could be attributed to skill heterogeneities, it is important to consider the role of firm-specific skill-biased change on heterogeneities in productivity, firm performance and export diversification/product sophistication. However, this affects wage premium.

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