Introducing the Effects of Foreign Direct Investment Into the GTAP-GAC Model

CoPS Working Paper No. G-333, July 2022

Peter B. Dixon
And
Maureen T. Rimmer
Centre of Policy Studies,
Victoria University

ISSN 1 921654 02 3 ISBN 978-1-921654-40-4

The Centre of Policy Studies (CoPS), incorporating the IMPACT project, is a research centre at Victoria University devoted to quantitative analysis of issues relevant to economic policy.
Address: Centre of Policy Studies, Victoria University, PO Box 14428, Melbourne, Victoria, 8001
home page: www.vu.edu.au/CoPS/ email: copsinfo@vu.edu.au Telephone +61 3 9919 1877

About us

Researchers at the Centre of Policy Studies have a 45-year history of continuous achievement in the development, application and dissemination of large-scale economic models. Our models and software are used around the world to analyse a diverse range of economic issues. CoPS' funders include: Australian federal and state government departments; private firms and universities in many parts of the world; central government agencies such as finance and trade ministries in many countries; and international development organisations. The Centre's GEMPACK software, used for solving large economic models, is used at more than 700 sites in over 95 countries.

Citation

Dixon, P.B. and Maureen T. Rimmer (2022), "Introducing the effects of foreign direct investment into the GTAP-GAC Model", Centre of Policy Studies Working Paper No. G-333, Victoria University, July 2022.

Introducing the effects of foreign direct investment into the GTAP-GAC model

by

Peter B. Dixon and Maureen T. Rimmer

Centre of Policy Studies, Victoria University, Melbourne

July 12, 2022

Abstract

Since 2018, we have built a series of GTAP models for Global Affairs Canada (GAC). Each of these models introduces modifications to the standard GTAP model. This paper describes GTAP-GAC3 in which we add an FDI extension. Our main focus is on the role of foreign-affiliate production as a substitute for imports and thereby a method for getting behind a tariff wall. GTAP-GAC3 could also be used for investigating scenarios in which FDI is motivated by productivity effects. Relative to other CGE models that incorporate FDI, GTAP-GAC3 has several advantages, including: year-on-year dynamics; realistic labour-market responses and high levels of commodity and country disaggregation. As explained in the paper, these advantages are achieved mainly by simplifications in demand-side specifications relative to those in other FDI-extended CGE models. By comparing GTAP-GAC3 tariff simulations conducted without and with the FDI extension, we show that FDI can have significant implications for simulation results.

JEL codes: C68; F21; F23

Key words: Foreign direct investment; computable general equilibrium modelling; GTAP model

Table of contents

Summary

(1) We add an FDI extension to the GTAP-GAC model. With this extension included, we refer to the model as GTAP-GAC3.

(2) The extension has been added to GTAP-GAC2 as a self-contained set of equations that can be turned on and off. This has obvious advantages in terms of learning how to use the extended model and in understanding how the FDI add-on affects results.

(3) The extension uses data on outputs for 57 GTAP commodities by foreign affiliates located in each of the 10 GTAP-GAC3 countries. The data were compiled at the USITC. They refer to 2005-2007. Updated data has been prepared at the USITC but is not yet publically available. When released it could be easily incorporated into the model.

(4) Our main focus is on the role of foreign-affiliate production as a substitute for imports and thereby a method for getting behind a tariff wall. Nevertheless, GTAP-GAC3 could be used for investigating scenarios in which FDI is motivated by productivity effects.

(5) Relative to other CGE models that incorporate FDI, GTAP-GAC3 has several advantages, including: year-on-year dynamics; realistic labour-market responses and high levels of commodity and country disaggregation. As explained in the paper, these advantages are achieved mainly by simplifications in demand-side specifications relative to those in other FDI-extended CGE models.

(6) By comparing GTAP-GAC3 tariff simulations conducted without and with the FDI extension, we show that FDI can have significant implications for simulation results. This applies both to directly affected industries and the macro economy. In the case of the Trump-era proposal for the U.S. to impose a 25 per cent tariff on imports of Finished vehicles from non-NAFTA countries together minor intra-NAFTA tariffs, we found that recognition of FDI effects led to:

- additional simulated benefits to the U.S. Motor vehicle industry;
- reduced simulated benefits to the Canadian Motor vehicle industry;
- less simulated loss to the U.S. macro economy; and
- less simulated gain to the Canadian macro economy.

1. BACKGROUND AND INTRODUCTION

In 2018-19, the Centre of Policy Studies (CoPS) created a version of the GTAP model for use by Global Affairs Canada (GAC). We referred to this model as GTAP-mvh. Relative to the standard version of GTAP (see for example, Corong *et al.*, 2017), GTAP-mvh provided:

- a highly disaggregated treatment of the motor vehicle sector (hence the designation mvh);
- an option to treat physical capital as specific to each industry in each region, rather than the standard GTAP specification in which physical capital is completely mobile between industries in a region;
- a sticky wage adjustment mechanism giving a realistic labor-market specification between the two standard GTAP extremes of either complete wage adjustment and full employment or fixed wages and adjusting employment; and
- a reformulation of GTAP's treatment of foreign assets and liabilities to account for net foreign asset accumulation in each region.

GTAP-mvh is documented in two working papers (Dixon *et al.,*2019 a & b) and was supplied to Global Affairs Canada together with illustrative simulations.

In 2019-21, the Centre of Policy Studies added a facilities to GTAP-mvh to enhance GAC's ability to use the model to study labour market and distributional effects of trade policies. With these facilities in place, we referred to the model as GTAP-GAC2. Documentation and illustrative applications were supplied to Global Affairs Canada in two reports (Dixon and Rimmer, 2020 & 2021).

In this paper we document another extension of GTAP. We add to GTAP-GAC2 equations and variables to handle a key aspect of FDI: the use of production in country h of foreign affiliates from country o to replace exports from o to h. With this extension, we refer to the model as GTAP-GAC3.

The paper is organized as follows. In the rest of this section we briefly review some relevant literature and outline our approach for GTAP-GAC3. In section 2 we describe the theory of our FDI extension. In section 3 we document the data used in developing the FDI extension. Section 4 provides an illustrative application. Concluding remarks are in section 5. The major theoretical treatment of FDI is Markusen (2002). The Appendix summarizes Markusen's approach and contrasts it with that adopted in GTAP-GAC3 in which our starting point was work by researchers at the U.S. International Trade Commission (USITC).

1.1. FDI in CGE models

FDI occurs when a firm in region o sets up production facilities in h, $o \neq h$, or acquires a controlling interest in existing firms in h. Starting with the work of Petri (1997), considerable research effort has been devoted to working out how to include FDI in CGE models focused on trade. In the GTAP community the best known work was undertaken at the U.S. International Trade Commission (USITC) by Lakatos and Fukui (2014).

Following Petri's approach, Lakatos and Fukui generalize the Armington assumption. Under the Armington assumption, agents in each country d treat product j produced in countries ℓ and m as imperfect substitutes. In Lakatos and Fukui's model, agents in country d go further. They treat product j produced in country ℓ by firms owned by country p as an imperfect substitute for product j produced in country ℓ by firms owned by country q. The work started by Lakatos and Fukui is being continued at the USITC by Yuan and Tsigas (2020).

Their effort was described at a conference held by the USITC in November 2020. Full documentation is not yet available, but based on the presentation and accompanying slide deck, we can see that Yuan and Tsigas' approach is as follows.

Demand side

Each region d's demands for commodity j are satisfied by a combination of domestic and imported j (an Armington nest).

Domestic j is a combination (CES nest) of j produced by d's own firms and by affiliates of foreign firms located in d. d's imports of j are a combination of j from regions external to d.

d's imports of j from region k are a combination of j produced by k's own firms and by foreign affiliates in k identified by ownership countries.

Supply side

Relative to the demand-side specification, Yuan and Tsigas adopt a stripped-down specification for supply. They introduce the concept of d's national capital in industry j. This is industry-j capital used by d's firms domestically and by d's affiliates in all other regions. Yuan and Tsigas assume that d's national capital in industry j is exogenous. In their model, this exogenous quantity of capital is reallocated endogenously between production of j in d and production of j in d's affiliates in other countries. The reallocation is in response to changes in relative rates of return on the use of capital at home and by affiliates.

In common with Lakatos and Fukui's model, Yuan and Tsigas' model is comparative static. It does not recognize the investment process. Country d's national capital in industry j can be reallocated to an affiliate in region k without requiring additional construction and purchase of machinery in country k or reduced construction and purchase of machinery in country d. Although they focus on foreign direct investment, Yuan and Tsigas's comparative-static approach inhibits their ability to track accumulation for each region of foreign assets and liabilities and related international income flows.

In common with standard applications of the GTAP model, Yuan and Tsigas set employment in each region exogenously. This means that there is no connection recognized in their model between aggregate employment in a region and FDI.

1.2. FDI in GTAP-GAC3

By embedding our FDI extension in GTAP-GAC3, we automatically provide a more policy relevant supply-side and macro framework than is available in previous CGE models with FDI extensions. GTAP-GAC3 includes all of the features listed at the beginning of this section in a dynamic model. We also include a mechanism for determining the ownership composition of output in each industry and country. The mechanism relies on a single technology for each industry in each country. The technology can be adjusted in simulations concerned with the role of FDI in affecting productivity in host countries.

Relative to other FDI-enhanced CGE models, GTAP-GAC3 presents a stripped-down demand side. In the Yuan and Tsigas model and other Petri extensions, the emphasis is on the role of FDI in providing host countries with an enriched range of choices. If there are 10 countries then there are potentially 100 varieties of each commodity j available to users in every country. In GTAP_GAC3, households, firms and government in each country continue, as in standard GTAP, to have Armington preferences: for each commodity they substitute between a single domestically produced product and an import composite. To cover the idea that a U.S. tariff against cars from Japan stimulates U.S. production by Japanese affiliates we introduce a twist in the Armington preferences towards the domestic product away from imports, recognizing that affiliate production increases the substitutability of cars produced in the U.S. for imports from Japan. In this way we avoid the dimensional increase that happens when demand specifications include an explicit ownership argument. This helps us to produce a computationally feasible model that is dynamic and includes a high level of industry and country detail.

2. THEORY

In working out how to include FDI in GTAP-GAC3, we were guided by the comprehensive theoretical exposition by Markusen (2002). He argues that FDI doesn't have much to do with financial investment. A firm in region o may set up an affiliate in region h using finance from region k. Thus for example, current-account surplus countries such as China can own large amounts of equity in many other countries without doing much FDI. A country's current account deficit is essentially determined by the savings of its residents relative to investment in the country, not by the nationality of the firms that undertake the investment. This is relevant for us, because it means that we can include FDI in GTAP-GAC3 without having to change our treatment of financial flows.

Markusen mentions that most FDI is horizontal. FDI creates factories that serve the local market with similar products to those produced by the parent company. This is also relevant for us. It means that we should focus on the role of FDI as a mechanism for avoiding tariff barriers and other trade costs.

In implementing Markusen's ideas in GTAP-GAC3, we were able to include FDI theory through equations that are simply added to GTAP-GAC2. These equations can be turned off by closure choices. Being able to implement the FDI theory in this way has obvious advantages in terms of learning how to use the extended model and in understanding how the FDI add-on affects results.

We present the theory in two subsections. Subsection 2.1 is concerned with the role of FDI in affecting the response of domestic output (output of domestically owned firms and foreign affiliates) to changes in the costs of imports relative to domestic output. Subsection 2.2 deals with the response of the ownership composition of domestic output to trade barriers.

2.1. Modifying GTAP outcomes for import/domestic ratios taking account of foreign-affiliate activity

In the standard GTAP model and in GTAP-GAC2, industry i in country h produces a single homogeneous product. In these models, we can measure the impact contribution to the output of good i in country h [good (i,h)] from a change in imports of (i,h) as:

$$\text{StandardImpact(i,h)} = -\frac{\text{VM(i,h)}}{\text{VO(i,h)}} * \text{qm(i,h)} \qquad (2.1)$$

where VM(i,h) and VO(i,h) are the values of imports and output of i in country h and qm(i,h) is the percentage change in the quantity of imports of (i,h). For example, if the ratio of imports to output for good i in country h is 0.4 and imports fall by 10 per cent, then

$$\text{StandardImpact}(i,h) = 4\% \ ,$$

meaning that producers in country h have the opportunity to make an import-replacing expansion in output of 4 per cent.

The RHS of (2.1) can be disaggregated into contributions from imports by source:

$$\text{StandardImpact}(i,h) = -\sum_{o \neq h} \frac{VM(i,o,h)}{VO(i,h)} * qm(i,o,h) \qquad (2.2)$$

where VM(i,o,h) is the value of h's imports of i from country o and qm(i,o,h) is the percentage change in the quantity of these imports.

In our expanded model with recognition of foreign affiliates, we assume that industry i in country h produces N varieties of good i differentiated by ownership, where N is the number of countries. Denoting the value of output of commodity i in country h by affiliates of country o as VO(i,h,o) gives

$$VO(i,h) = \sum_{o} VO(i,h,o) \qquad (2.3)$$

In country h we assume that good i imported from country o substitutes more easily with the o-variety produced in h that with other varieties produced in h. For example, we assume that cars imported by the U.S. from Japan are particularly good substitutes for cars produced in the U.S. by Japanese affiliates. To take this idea into account, we calculate a modified version of the impact contribution to the output of i in country h from a change in imports of i:

$$\text{ModImpact}(i,h) = -\sum_{o \neq h} \left[1 + \alpha \left(\frac{\dfrac{VO(i,h,o)}{VO(i,h) - VO(i,h,h)}}{\dfrac{VM(i,o,h)}{VM(i,h)}} - 1 \right) \right] * \frac{VM(i,o,h)}{VO(i,h)} * [qm(i,o,h)] \qquad (2.4)$$

where α is a parameter with value between 0 and 1.

In (2.4), the contribution to (i,h)-output of changes in imports of i from country o is given extra weight if the share of o in foreign affiliate production of i in h is greater than the share of o in imports of i by h. Via (2.4), we recognize that country h has enhanced capability for replacing imports of i from o if country o has a strong affiliate representation in the i-industry in h.

On the assumption that the standard impact given by (2.2) is already present in standard GTAP, we add an extra impact to (i,h) output from changes in imports in the FDI-extended version of GTAP according to:

$$\text{ExtraImpact}(i,h) = \text{ModImpact}(i,h) - \text{StandardImpact}(i,h) \qquad (2.5)$$

That is:

$$\text{ExtraImpact}(i,h) = -\sum_{o \neq h} \left[\alpha \left(\frac{\dfrac{VO(i,h,o)}{VO(i,h) - VO(i,h,h)}}{\dfrac{VM(i,o,h)}{VM(i,h)}} - 1 \right) \right] * \frac{VM(i,o,h)}{VO(i,h)} * \left[qm(i,o,h) \right] \quad (2.6)$$

To impose ExtraImpact(i,h) on the output of (i,h) we use a movement in twist_src(i,h). This is a variable that we added to equations in GTAP-GAC2 that depict demands in country h by households, government and firms for imported and domestic units of good i. With suitable coefficients attached, movements in twist_src(i,h) cause cost-neutral changes by domestic agents in country h in the ratio of their demands for imported varieties to domestic varieties of commodity i. A positive value for twist_src(i,h) increases import/domestic ratios but doesn't affect an agent's overall use of commodity i. In the absence of other shocks:

$$qm(i,h) - qd(i,h) = twist\_src(i,h) \quad (2.7)$$

and

$$S_M(i,h) * qm(i,h) + (1 - S_M(i,h)) * qd(i,h) = 0 \quad (2.8)$$

where,

as earlier, qm(i,h) is the percentage change in the quantity of imports of i to h;

qd(i,h) is the percentage change in the quantity of i produced in h that is absorbed in h (output excluding exports); and

$S_M(i,h)$ is the share of imports in domestic demand for i in h, which can be calculated as:

$$S_M(i,h) = \frac{VM(i,h)}{VM(i,h) + VO(i,h) - VX(i,h)} \quad (2.9)$$

where VX(i,h) is exports of i from h.

Under equation (2.7), twist_src(i,h) imposes a shift in the import/domestic ratio of absorption of i in h. Under (2.8), this shift takes place with no change in the overall absorption of i in h.

Working with (2.7) and (2.8) we find that the impact effect on domestic demand for domestic i in h of a movement in twist_src(i,h) is given by

$$qd(i,h) = -S_M(i,h) * twist\_src(i,h) \quad (2.10)$$

In view of (2.10) we impose the extra FDI-related impact on the output of (i,h) by setting twist_src(i,h) according to:

$$twist\_src(i,h) = -\frac{1}{S_M(i,h)} * \text{ExtraImpact}(i,h) \quad (2.11)$$

Hence we set twist_src(i,h) as:

$$\text{twist\_src}(i,h) = \left[\frac{VM(i,h)+VO(i,h)-VX(i,h)}{VM(i,h)}\right] * \sum_{o \neq h}\left[\alpha\left(\frac{\dfrac{VO(i,h,o)}{VO(i,h)-VO(i,h,h)}}{\dfrac{VM(i,o,h)}{VM(i,h)}}-1\right)\right] * \frac{VM(i,o,h)}{VO(i,h)} * [qm(i,o,h)] \tag{2.12}$$

which reduces to

$$\text{twist\_src}(i,h) = \alpha * \frac{VM(i,h)+VO(i,h)-VX(i,h)}{VO(i,h)} * \sum_{o \neq h}\left[\left(\frac{VO(i,h,o)}{VO(i,h)-VO(i,h,h)} - \frac{VM(i,o,h)}{VM(i,h)}\right)\right] * [qm(i,o,h)] \tag{2.13}$$

How should we set α? $\alpha = 0$ is too low: it denies an FDI effect. $\alpha = 1$ is too high: it implies that import replacement is done entirely by foreign affiliates. In the illustrative simulations in section 4, we set $\alpha = 0.25$. We arrived at this value after judging that higher values lead to results that were unrealistically extreme. For example, with $\alpha = 0.5$ we found that tariff increases by the U.S. against motor-vehicle imports from non-NAFTA countries gave simulated output increases in the U.S. by non-NAFTA affiliates that were sufficiently strong to imply output reductions by U.S. owned firms in the U.S.

2.2. Disaggregating output of commodity i in country h into outputs by domestically owned firms and firms owned by each other country

When the competitive position of o-firms in country h's industry i improves relative to that of other i-producing firms in h, we want our model to show how the composition of output of i in h moves in favour of o-firms. In particular, we want our model to show that i-producing o-owned firms in country h benefit relative to other i-producing firms in h from trade barriers imposed by h on imports from o. This subsection explains how that effect is achieved in GTAP-GAC3.

We start by assuming that:

$$p(i,h,o) - p(i,h) = \beta * pimp(i,o,h) - \sum_k SHVO\_O(i,h,k) * \beta * pimp(i,k,h) \tag{2.14}$$

where

β is a positive parameter with value less than 1;

p(i,h,o) is the percentage change in the factory-door price (market price in GTAP language) of commodity i produced in country h by firms owned by country o;

pimp(i,o,h), $o \neq h$, is the percentage change in the landed-duty-paid price in country h of commodity i imported from country o (also a market price in GTAP language);

pimp(i,h,h) is the same as p(i,h); and

p(i,h) is the average factory-door price of commodity i produced in h, which via (2.14) is given by:

$$p(i,h) = \sum_{o} SHVO\_O(i,h,o) * p(i,h,o) \qquad (2.15)$$

where

SHVO_O(i,h,o) is the share of o-firms in the value of output of commodity i in country h.

The LHS of (2.14) is the percentage deviation in the price charged by o-firms producing commodity i in country h from the average price of i-producing firms in h. Ignoring for a moment the last term on the RHS, (2.14) indicates that o-firms producing i in h will increase their prices relative the average price if the price of imports from o increases. For example, if a tariff imposed by the U.S. on imports of Japanese cars causes pimp(cars,Japan,U.S.) to be 25, and β is set at 0.5, then the first term on the RHS means that the price of Japanese cars produced in the U.S. [p(Cars,U.S.,Japan)] increases by 12.5% relative to the average price of cars produced in the U.S. [p(Cars,U.S.)]. The last term on the RHS of (2.14) is necessary to ensure that p(i,h) is a sensibly defined average: it ensures that (2.15) holds.

Next we assume that activity in industry (i,h) is allocated across the domestically owned and foreign affiliates in a way that maximizes

$$\sum_{o} P(i,h,o) * QO(i,h,o) \qquad (2.16)$$

subject to

$$QO(i,h) = CET_{i,h}\left[QO(i,h,1),...,QO(i,h,N)\right] \qquad (2.17)$$

where

QO(i,h,k) is the output of i in h by k-owned firms;

QO(i,h) is the total output of i in h; and

P(i,h,o) is the price to producers of the o-owned variety of commodity i in h [the levels version of p(i,h,o)].

In percentage changes, optimization problem (2.16) - (2.17) implies that

$$q(i,h,o) = q(i,h) + \sigma s * \left(p(i,h,o) - p(i,h)\right) \qquad (2.18)$$

where

p(i,h) is defined in (2.15);

qo(i,h,0) is the percentage change in QO(i,h,o);

qo(i,h) is the percentage change in QO(i,h); and

σs is a positive parameter.

With (2.14) and (2.18) in place, trade barriers imposed by h on imports of i from o will increase the output of i in h by o-firms relative to total output of i in h.

Finally, we note that the inclusion of (2.14) and (2.18) in GTAP-GAC3 affects only the results for the ownership composition of output of each commodity in each country. There is no feedback to other variables in the model: overall quantity and price movements, qo(i,h) and p(i, h) come from other parts of the model and are not affected by our assumptions concerning ownership allocation. This is reassuring because in setting values for the critical parameters, β and σs, we must rely on judgement, uninformed by empirical evidence. In the illustrative application in section 4, both of these parameters are set at 0.5.

3. DATA

To implement the theory in section 2, we need data on the ownership composition of output by commodity and country, VO(i,h,o). A dataset compatible with GTAP industries has been compiled by Fukui and Lakatos (2012). This shows $US values of outputs for 57 GTAP commodities by foreign affiliates located in 129 countries or regions. Fukui and Lakatos describe the data as referring to an average year between 2005 and 2007. Unfortunately their data do not show output by domestically owned firms: it leaves out VO(i,h,h). We made a preliminary calculation of the missing data according to:

$$\mathrm{VO}(i,h,h) = \mathrm{VO}_{2004}(i,h) - \sum_{o \neq h} \mathrm{VO}_{F\&L}(i,h,o) \tag{3.1}$$

where

$VO_{2004}(i,h)$ is the value of output of i in country h in the GTAP database for 2004 (the closest GTAP database to 2005-7); and

$VO_{F\&L}(i,h,o)$ is the Fukui & Lakatos estimate of the value of output of i by o-owned firms in country h.

Matching data in (3.1) for somewhat different years is not ideal and in fact gave a few negatives estimates for VO(i,h,h). We corrected this problem by assuming that the minimum share for domestically owned i in country h is 20 per cent of total output of i in country h and achieved this by proportionately scaling down the $VO_{F\&L}(i,h,o)$ data for $o \neq h$. After making this correction, we computed ownership shares in the output of each commodity in each country [SHVO_O(i,h,o) in the notation of section 2].

The USITC is updating the Fukui and Lakatos estimates. This updating project is described by Yuan and Tsigas (2020). Data from the updating project is not yet publically available. The database year for GTAP-GAC3 is 2015. In the absence of the updated data we assumed that our ownership shares derived from Fukui and Lakatos are applicable for 2015. Applying these shares we were able to derive 2015 values for VO(i,h,o) for all i, h and o. In simulation, these values are updated reflecting simulated movements in prices and quantities.

In GTAP-GAC3, the motor-vehicle industry in each country is disaggregated into 9 sub-industries. The foreign-affiliate data does not include this disaggregation. To cover this gap we assumed for each country that the same ownership shares applied in 2015 to all the sub-industries. Ownership shares in the Motor vehicle sub-industries can move apart in simulations beyond 2015.

The illustrative application in section 4 is concerned with motor-vehicle tariffs. For this application the most relevant part of our FDI database is the ownership shares that we adopt for the Motor vehicle sector of each country. These are shown in Table 3.1.

Table 3.1. Ownership shares in the Motor-vehicle sectors of producing countries, 2015

Owners / Producers	USA	Canada	Mexico	Japan	SKorea	China	Germany	EU26	UK	RoW	Total
USA	0.509	0.007	0.001	0.211	0	0.05	0.082	0.013	0.001	0.126	1
Canada	0.024	0.739	0	0	0	0	0.101	0.135	0	0	1
Mexico	0.631	0	0.363	0	0	0	0.003	0.002	0	0.001	1
Japan	0.028	0	0	0.967	0	0	0.005	0	0	0	1
SKorea	0.154	0	0	0	0.842	0.001	0.001	0.001	0	0.001	1
China	0.104	0	0	0.001	0	0.827	0.047	0.013	0.003	0.004	1
Germany	0.231	0	0	0.005	0	0	0.729	0.023	0	0.010	1
EU26	0.278	0	0	0.005	0	0	0.246	0.447	0.003	0.020	1
UK	0.566	0.002	0	0.002	0	0.003	0.161	0.019	0.241	0.006	1
RoW	0.615	0	0	0	0	0.001	0.090	0.093	0	0.200	1

4. ILLUSTRATIVE APPLICATION OF GTAP-GAC3

As in our reports on GTAP-GAC2 (Dixon and Rimmer, 2020 &2021), we illustrate the application of GTAP-GAC3 by simulating the effects of the tariff increases in Table 4.1. Although these tariff increases were proposed as part of Trump-era policies, for our illustrative application we assume that they are imposed in 2016.

A simulation with GTAP-GAC3 consist of two runs. The first is a bland baseline provided by the GTAP Center at Purdue based mainly on World Bank and IMF forecasts. The second imposes the tariff increases from Table 4.1 on top of the baseline. We report the effects of the tariff increases as deviations from the baseline calculated as differences between the two runs.

We conduct two simulations: one without the FDI add-on discussed in section 2 and one with the add-on. The simulations produce results for each year from 2016 to 2023. The transitions in the results through this period are almost smooth. Most of the picture of what happens is captured by the deviation results for the first and last years. Consequently, in the tables of results (Tables 4.2 to 4.4) we report deviations for just these two years. Macro results for all years for the U.S. and Canada can be seen in Figures 4.1 and 4.2.

Table 4.1. Proposed percentage increases in powers of tariffs on finished vehicles: commodities 38 & 46 in GTAP-GAC3

on imports from:	**Tariff imposed by:** U.S.	Canada	Mexico
U.S.		2.5	10.8
Canada	0.7		6.4
Mexico	1.1	3.1	
Non-NAFTA countries	25.0	0.0	0.0

Table 4.2. Percentage effects on outputs of Motor vehicles (deviations from baseline)

	Without FDI effects		**With FDI effects**	
	2016	***2023***	***2016***	***2023***
Motor vehicles				
1 USA	4.44	5.20	5.93	7.59
2 Canada	5.70	14.39	3.01	7.31
3 Mexico	1.16	7.17	0.72	4.24
4 Japan	-4.12	-5.57	-4.84	-6.35
5 SKorea	-1.77	-3.96	-2.11	-4.60
6 China	-0.72	-1.06	-0.68	-1.12
7 Germany	-3.14	-3.15	-3.79	-3.66
8 EU26	-0.79	-1.22	-0.99	-1.51
9 UK	-2.34	-2.74	-2.20	-2.91
10 RoW	-0.54	-0.79	-0.10	-0.39
Finished vehicles				
1 USA	5.69	6.07	7.81	9.48
2 Canada	7.75	18.14	4.06	9.04
3 Mexico	1.70	9.64	1.01	5.48
4 Japan	-5.50	-6.73	-6.47	-7.64
5 SKorea	-3.03	-6.05	-3.63	-6.99
6 China	-1.02	-1.50	-1.00	-1.61
7 Germany	-4.09	-4.20	-4.98	-4.86
8 EU26	-0.80	-1.26	-1.02	-1.55
9 UK	-2.55	-3.04	-2.36	-3.21
10 RoW	-0.61	-0.92	-0.09	-0.48
Vehicle parts				
1 USA	2.09	3.53	2.40	3.94
2 Canada	1.56	6.41	0.96	3.77
3 Mexico	-0.10	1.34	0.06	1.43
4 Japan	-3.68	-5.18	-4.31	-5.92
5 SKorea	-0.81	-2.36	-0.95	-2.77
6 China	-0.58	-0.88	-0.54	-0.93
7 Germany	-1.84	-1.69	-2.18	-1.99
8 EU26	-0.76	-1.15	-0.94	-1.43
9 UK	-1.32	-1.26	-1.43	-1.40
10 RoW	-0.35	-0.43	-0.11	-0.15

4.1. Results for the Motor vehicle sector

The tariff shocks in Table 4.1 can be thought of as: (a) small intra-NAFTA tariff increases; and (b) a 25 per cent U.S. tariff against imports of Finished vehicles from non-NAFTA countries. The (b) shocks are generally dominant in the results.

Without FDI effects (as in GTAP-GAC2)

The left panel of Table 4.2 shows that without FDI effects the proposed tariff on Finished motor vehicles would stimulate U.S. output of both Finished vehicles and Vehicle parts. It also has a stimulatory effect in the Motor vehicle sector in the other two NAFTA countries.

Figure 4.1. Effects on macro variables in Canada from the tariff increases in Table 4.1 (percentage deviations from baseline)

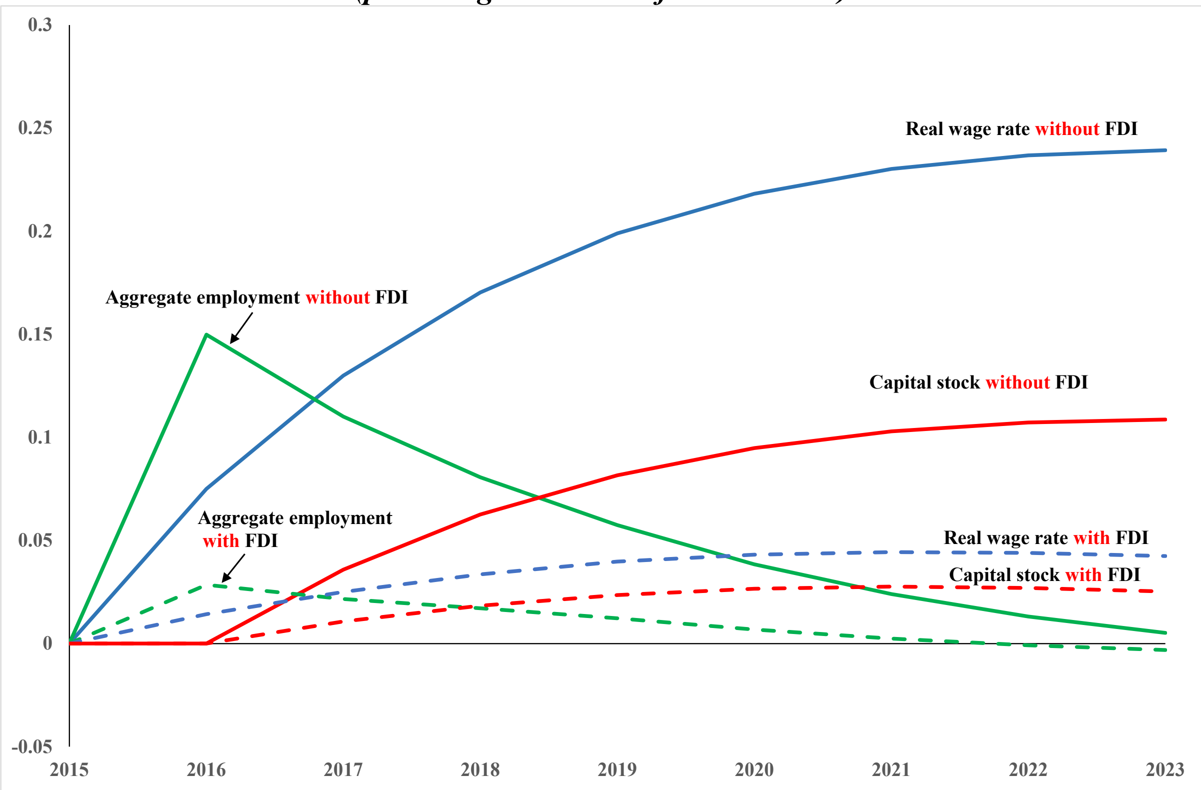


Figure 4.2. Effects on macro variables in the U.S. from the tariff increases in Table 4.1 (percentage deviations from baseline)

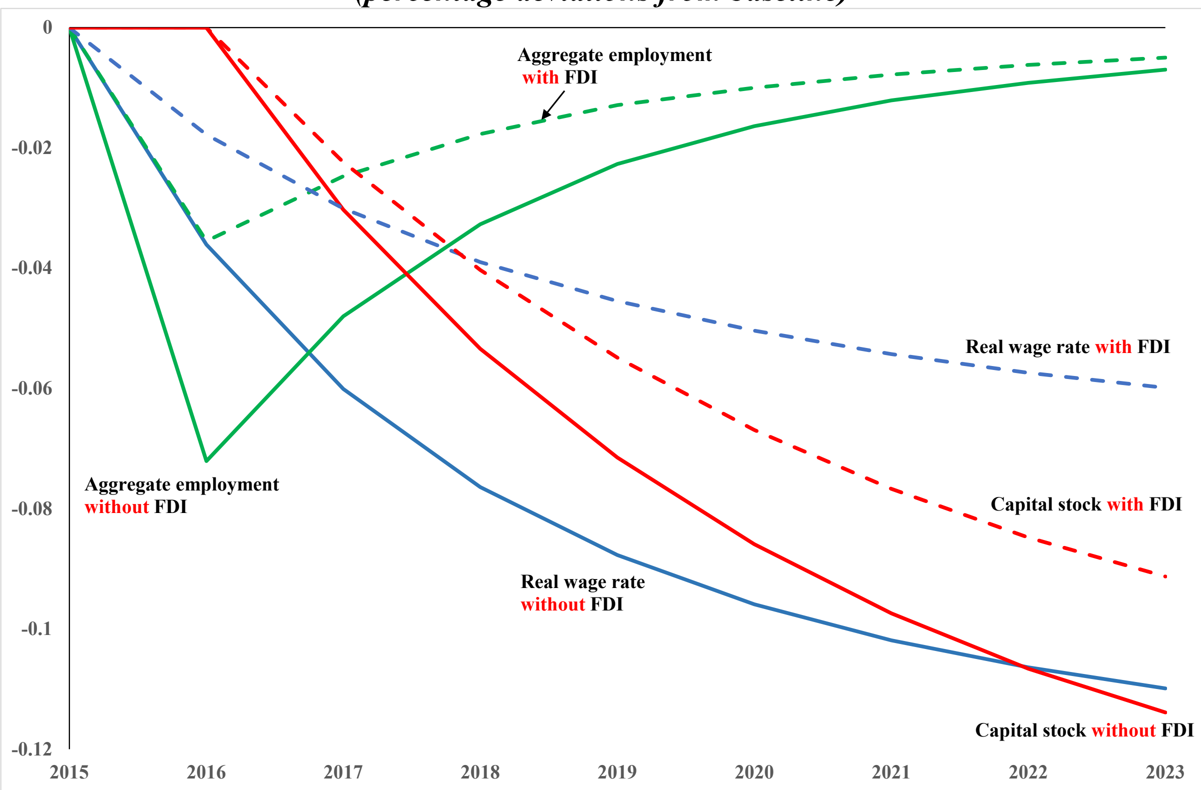


Table 4.3. Output in the Motor vehicle sector by ownership in the U.S. and Canada: Percentage deviations from baseline in the simulation with FDI

	USA		Canada	
	2016	***2023***	***2016***	***2023***
1 USA	4.24	5.69	3.36	7.75
2 Canada	4.60	5.87	3.17	7.37
3 Mexico	4.73	6.11	3.72	8.10
4 Japan	7.52	9.48	2.26	6.95
5 SKorea	7.50	9.50	2.24	6.97
6 China	7.78	9.62	2.51	7.09
7 Germany	7.77	9.59	2.50	7.06
8 EU26	7.75	9.62	2.48	7.09
9 UK	7.81	9.62	2.55	7.09
10 RoW	7.85	9.63	2.57	7.10
Total vehicle output	5.93	7.59	3.01	7.31

Output of Finished vehicles in these countries benefits from reduced competition in the U.S. market from non-NAFTA countries. Vehicle parts production in Canada benefits from expansion in its own Finished vehicle industry and that of the U.S.

The results for Vehicle parts production in Mexico in the early years of the simulation are negative. Mexico is a major beneficiary from the U.S. tariff on Finished vehicles (includes trucks) from non-NAFTA countries. Associated real appreciation of the Mexican currency initially hurts its Vehicle parts sales outside Mexico.

Motor vehicle production in non-NAFTA countries shows strongly negative effects, especially for Japan for which the U.S. is a major market.

In most cases positive results for 2016 become more positive by 2023 and negative results become more negative. This reflects gradual adjustment of industry capital stocks. Favourable effects for an industry in 2016 stimulate investment in the industry leading to increased capital and output in future years. Unfavourable effects in 2016 act in the opposite direction.

With FDI effects

The introduction of FDI accentuates the favourable effects for the U.S. Motor vehicle industry (right panel of Table 4.2). In the U.S., foreign affiliate production is dominated by Non-NAFTA countries, particularly Japan and Germany. Under the theory set out in section 2, recognition of FDI means that import-replacement generated by the U.S. 25 per cent tariff on Non-NAFTA imports of Finished vehicles is enhanced relative to the situation in which FDI effects are left out. Recognition of FDI causes the Motor vehicle results in Table 4.2 for Japan and Germany to be more negative. Increased import replacement in the U.S. by affiliates of these countries reduces their home-country output.

Table 4.4. Percentage effects on macro variables

	Without FDI		With FDI	
	2016	*2023*	*2016*	*2023*
Real GDP				
1 USA	-0.083	-0.074	-0.060	-0.068
2 Canada	0.109	0.063	0.027	0.019
3 Mexico	0.060	0.196	0.020	0.087
4 Japan	-0.077	-0.039	-0.093	-0.047
5 SKorea	-0.071	-0.075	-0.089	-0.088
6 China	-0.001	-0.004	-0.003	-0.006
7 Germany	-0.078	-0.001	-0.095	-0.005
8 EU26	-0.001	-0.001	-0.005	-0.006
9 UK	-0.021	-0.005	-0.018	-0.007
10 RoW	0.011	0.011	0.010	0.009
Employment				
1 USA	-0.072	-0.007	-0.036	-0.005
2 Canada	0.150	0.005	0.029	-0.003
3 Mexico	0.119	0.036	0.045	0.010
4 Japan	-0.120	-0.013	-0.145	-0.014
5 SKorea	-0.111	-0.031	-0.135	-0.034
6 China	-0.005	-0.005	-0.003	-0.005
7 Germany	-0.127	0.001	-0.153	0.002
8 EU26	0.004	-0.002	-0.001	-0.003
9 UK	-0.027	-0.004	-0.021	-0.005
10 RoW	0.017	-0.002	0.020	-0.002
Capital				
1 USA	0.000	-0.114	0.000	-0.091
2 Canada	0.000	0.109	0.000	0.025
3 Mexico	0.000	0.261	0.000	0.129
4 Japan	0.000	-0.054	0.000	-0.068
5 SKorea	0.000	-0.099	0.000	-0.118
6 China	0.000	-0.008	0.000	-0.009
7 Germany	0.000	-0.002	0.000	-0.010
8 EU26	0.000	0.008	0.000	0.003
9 UK	0.000	0.009	0.000	0.008
10 RoW	0.000	0.022	0.000	0.022
Real private & public consumptiom				
1 USA	-0.056	-0.022	-0.024	-0.006
2 Canada	0.155	0.077	0.036	0.014
3 Mexico	0.295	0.205	0.159	0.099
4 Japan	-0.096	-0.064	-0.118	-0.078
5 SKorea	-0.159	-0.169	-0.193	-0.197
6 China	-0.008	-0.010	-0.009	-0.011
7 Germany	-0.089	-0.039	-0.108	-0.054
8 EU26	0.004	0.016	-0.001	0.007
9 UK	-0.030	-0.025	-0.024	-0.025
10 RoW	0.018	0.020	0.016	0.015

The introduction of FDI damps the favourable effects for the Canadian motor vehicle industry. Nevertheless the effects are still favourable. Expansion of Canadian output is accompanied by price increases throughout the Canadian motor vehicle sector. There are also price reductions throughout the motor-vehicle sectors of Non-NAFTA countries which suffer output contraction. These two sets of price movements improve the competitive position of imports of motor-vehicle products to Canada from Non-NAFTA countries. Our FDI specification takes account of the damage to Canadian output of Non-NAFTA affiliates who lose market share to imports from their parent countries. Foreign affiliate production in Canada's motor vehicle sector is dominated by Non-NAFTA countries, particularly European countries. Thus, recognition of the loss of affiliate competitiveness against imports of motor-vehicle products from parent countries has a negative effect on Canadian output relative to the situation in which the ownership pattern of foreign affiliates in Canada is not taken into account.

Table 4.3 gives results from the simulation with FDI effects for output in the U.S. and Canadian motor-vehicle sectors disaggregated by ownership. In the U.S., the 25 per cent tariff on non-NAFTA countries causes Motor-vehicle output of affiliates from non-NAFTA countries to expand relative to output by U.S.-owned firms and affiliates from NAFTA countries. In Canada, the tariffs imposed against imports from NAFTA countries cause Motor-vehicle output by NAFTA-owned affiliates and Canadian-owned firms to expand relative to output by non-NAFTA affiliates.

4.2. Results for macro variables

Table 4.4 shows 2016 and 2023 results for both simulations for GDP, employment, capital stock and consumption (private plus public). Results for all years for Canada and the U.S. are in Figures 4.1 and 4.2.

Without FDI effects (as in GTAP-GAC2)

The solid lines in Figure 4.1 depict macro deviation paths for Canada in the simulation without FDI. These indicate positive outcomes in both the short and long runs. In the short run, Canada experiences employment gains associated with improved competitiveness in the U.S. Motor vehicle market. In the long run, wages in Canada adjust upwards and return employment towards its baseline path. Thus, in the long run, the benefit to Canada from its improved position in the U.S. motor vehicle market is reflected in higher real wages and an associated increase in its capital stock (a higher K/L ratio). Higher wage rates and GDP lead to positive deviations in Canada's private and public consumption. These deviations can be interpreted as welfare gains. Similarly Mexico improves its competitiveness in the U.S. motor-vehicle market, with positive macro effects in both the short run and long run (see Table 4.4).

The solid lines in Figure 4.2 depict macro deviation paths for the U.S. in the simulation without FDI. These indicate negative macro outcomes in both the short and long runs. The 25 per cent increase in tariffs by the U.S. against imports of Finished vehicles from non-NAFTA countries increases the costs of Finished cars & trucks to U.S. households and capital creators. These cost increases reduce the number of people who can be employed at current real wages. Eventually wages adjust down so that employment in the U.S. is restored to baseline. This process is almost complete by 2023. Even though the employment effects are eliminated in the long run, the GDP deviations for the U.S. remain negative. This is because the U.S. loses capital in the long run. With higher tariffs, capital must become scarcer for rates of return to be restored to baseline levels, or explained another way, reduced real wages mean that an economy's K/L ratio will fall implying, with L returning to baseline, a long-run reduction in K.

In explaining how the macro results for Canada and the U.S. are affected by the recognition of FDI, it is convenient to start with the U.S. Comparison of the dashed lines in Figure 4.2 with the solid lines shows a less unfavourable macro outcome for the U.S. with FDI than without. As we have already explained, macro damage to the U.S. in the without-FDI simulation is caused by the increase in the cost of motor vehicles to U.S. firms and households. This cost increase is no worse in the with-FDI simulation. At the same time, the improved outcome for the U.S. Motor-vehicle industry as we go to the with-FDI simulation has a macro benefit. This flows from a terms-of-trade improvement. The increase in output of Motor vehicles in the with-FDI simulation relative to the without-FDI simulation reduces U.S. imports of motor vehicles. This means that less exports of all products are needed to pay for imports of motor vehicles. Less exports gives a terms-of-trade improvement (an increase in the price index for exports relative to that for imports). A terms-of-trade improvement gives a short-run aggregate employment boost by allowing more people to be employed at any given real wage rate. It gives a long-run boost to real wages by allowing the same number to be employed at a higher real wage, and it generates a higher K/L ratio by increasing the cost of labour relative to the cost of capital.

Comparison of the dashed lines in Figure 4.1 with the solid lines shows a less favourable macro outcome for Canada with FDI than without. The explanation is similar to that which we have just given for the U.S. macro variables, but with opposite sign. As we move from the without-FDI simulation to the with-FDI simulation, Canadian output of Motor vehicles falls and Canadian imports of Motor vehicles rise. This imparts a terms-of-trade loss with negative macro consequences.

5. CONCLUDING REMARKS

GTAP-GAC3 is a tool for recognizing the role of FDI in modifying the response of imports to tariff changes and other trade policies. By comparing tariff simulations conducted without and with the FDI extension, we saw in section 4 that FDI can have significant implications for simulation results. This applies both to directly affected industries and the macro economy. In the case of the Trump-era proposal for the U.S. to impose a 25 per cent tariff on imports of Finished vehicles from non-NAFTA countries together minor intra-NAFTA tariffs, we found that recognition of FDI effects led to:

- additional simulated benefits to the U.S. Motor vehicle industry;
- reduced simulated benefits to the Canadian Motor vehicle industry;
- less simulated loss to the U.S. macro economy; and
- less simulated gain to the Canadian macro economy.

While our focus was on foreign affiliate production as a substitute for imports and thereby a method for getting behind a tariff wall, GTAP-GAC3 could also be used for investigating scenarios in which FDI has productivity effects.

The FDI extension in GTAP-GAC3 has two parts. On the demand-side we allow agents in each country to twist their preferences between imported and domestically produced products in response to foreign-affiliate production in the domestic economy. On the supply side, we allow the composition of domestic output to change in favour of affiliates in response to the imposition of trade barriers. However, the demand- and supply-side effects are modelled independently. This is not ideal from a theoretical point of view, but it has major simplifying benefits. It allowed us to include FDI without dimensionality problems in a dynamic model with realistic labour-market responses and high levels commodity and country disaggregation. Another benefit was that the FDI extension could be included as an add-on without changes to previous GTAP-GAC model.

It is disappointing that we had to implement GTAP-GAC3 with rather dated information on foreign-affiliate sales. There is a good prospect that this problem can be overcome with timely release of the USITC FDI update study. Finally, there is always the problem of parameters. As is clear from sections 2 and 4, several key parameters were set entirely by judgement. Without an enormous research budget, there is no alternative to this approach. With sensitivity simulations it would be straight-forward to assess the implications for key results of alternative views on parameter values within reasonable ranges.

APPENDIX. NOTES ON MARKUSEN'S THEORY OF FDI AND TRADE

A1. Markusen's FDI theory

Markusen (2002) provides a detailed statement of the theory of FDI and trade. He defines FDI as occurring when a firm in region s sets up production facilities in d, d≠s, or acquires a controlling interest in existing firms in s.

Markusen makes an important preliminary point. He argues that:

- FDI doesn't have much to do with financial investment. A firm in region s may set up an affiliate in region d using finance from region k. Thus for example, current-account surplus countries such as China can own large amounts of equity in many other countries without doing much FDI. This is relevant for us, because it means that we can include FDI in GTAP-GAC3 without having to include explicit financial flows.

Markusen mentions that most FDI appears to be horizontal. FDI creates factories that serve the local market with the same sort of products as the parent company produces. This means that from the point of view of the parent company, FDI replaces exports. This insight simplified our modelling because it meant that we didn't need to cope with the idea that FDI changes the input structure of the parent company. For example, we don't need to think of FDI as reducing the domestic operations of the parent company to the provision of HQ services.

According to Markusen the characteristics of industries in which FDI is important include: high levels of R&D to sales; high-skilled (professional labor); technically complex products; high levels of advertising; and high levels of intangible assets. In our modelling, we will be taking these factor as given. We can think of these characteristics as determining the current levels of FDI. We want to simulate how changes in policy variables affect FDI. For example, we will be concerned with how changes in trade barriers are likely to affect FDI.

Markusen's analytical method

Markusen builds a series of small numerical models (no real data). These are designed to show, for example,

> "*the effects of trade versus investment liberalization on factor prices, and the location of production.*" [page xv]

Markusen is concerned with how a firm should serve foreign markets. In most of the book, the choice is between exports and foreign production (requiring FDI). Another possibility he considers is licencing.

Overview of a Markusen model

To understand Markusen's analytical method and some of his key results, we work through his most basic model. In that model, he considers a firm in country i which is deciding between three possibilities for servicing demands for its product in country i's market and in a foreign market (country j). The three possibilities are:

i. Locate all its production facilities at home (country i) and export to country j. In this case, the firm remains a domestic or type d firm.
ii. Locate production facilities in country i to supply i's needs and in country j to supply j's needs. In this case, the firm becomes a horizontal multi-national (type h) firm.
iii. Locate production facilities in country j and use these to service both markets. In this case, the firm becomes a vertically integrated multi-national (type v) firm.

Under Markusen's set up there is no international trade with type h. Under types d and v, trade is one way: exports from i to j under d; and from j to i under v. These trade patterns are dictated by three assumptions: (1) the firm's product is identical irrespective of where it is produced (no Armington); (2) economies of scale in production, and (3) positive trade costs.

Markusen describes a model in which the firm has constant marginal costs which may differ between countries i and j. The firm also faces two types of fixed costs: a creation costs for the firm and a set up cost in each country. These fixed costs give the firm increasing returns to scale. Finally, the firm has monopoly power.

On the demand side, Markusen assumes there is a utility-maximizing household in each country who chooses between the firm's product and another product that is produced under constant returns to scale in a purely competitive market.

Markusen specifies stylized parameters and solves the model by first calculating 3 profit functions:

$$\Pi^d = f^d(L_i, L_j, C_i, C_j, G, F, T_i, T_j)$$

$$\Pi^h = f^h(L_i, L_j, C_i, C_j, G, F, T_i, T_j)$$

$$\Pi^v = f^v (L_i, L_j, C_i, C_j, G, F, T_i, T_j)$$

Π^d, Π^h and Π^v are the profits the firm makes under the three choices, d, h and v.

L_i and L_j are the populations (and also employment levels) in the two countries. These variables are used by Markusen as indicators of market size for the firm's products in the two countries.

C_i and C_j are the marginal costs for producing the firm's products in the two countries.

F and G are the fixed costs applying to the creation of the firm (F) and the set up costs of production facilities in each country (assumed the same for both countries).

T_j is the cost of sending 1 unit of the firm's product from country i to j (e.g. the tariff imposed by j) and T_i is the cost of sending one unit from j to i.

For any given values of L_i, L_j, C_i, C_j, G, F, T_i and T_j, what the firm does is determined by evaluating Π^d, Π^h and Π^v and choosing the d, h or v strategy giving the maximum Π value.

Markusen's model gives results suggesting that:

1. If the world gets bigger [L_i and L_j grow holding trade costs (T_i,T_j) and the other variables constant], then an h strategy becomes more likely. The intuition is that the costs of setting up plants in other countries becomes less onerous when the volume of output from these plants increases. This makes option h attractive relative to d and v which both incur trade costs.
2. If countries are of similar size then an h strategy becomes more likely. If one country is very large relative to the other, then the firm should locate production in the large country (strategy v or d) thereby gaining maximum economies of scale by producing for the world in one location while incurring only moderate trade costs because the firm doesn't have to export much to the smaller country.
3. The h strategy is more likely if T_i and T_j are high.
4. The h strategy is more likely if firm-specific costs (F) are high relative to other elements of the costs of servicing markets. This means horizontal multi-nationals are likely in industries with high R and D costs and global advertising costs.
5. The h strategy is more likely if marginal costs are similar in the two countries. If marginal costs are high in one country relative to the other, then the firm will tend to locate all production in the low cost country (strategy v or d).

Mathematical specification of a basic Markusen model

On page 34 Markusen sets out the notation for his most basic model.

(a) There are two countries, i and j.

(b) There are two goods, *X* and *Y*.

(c) There is one factor of production, *L*.

(d) *Y* is produced with constant returns by a competitive industry in both countries.

(e) *X* is produced by a single firm, headquartered in country i. Country j does not have domestic firms in industry *X* although it may host foreign affiliates.

(f) The *X* firm can have either

a single plant in country i:	a type-d (domestic or national) firm,
plants in both countries:	a type-h (horizontal multinational) firm, or
a single plant in country j:	a type-v (vertical multinational) firm.

(g) Markets are segmented so that the *X* firm can price independently in the two markets without threat of arbitrage.

Double subscripts are used for *X* and *Y*, with the first indicating the country of *production* and the second the country of *consumption*. X_{ii} is the amount of *X* produced and sold in country i. This is positive if the firm is type-d or h. X_{ij} is the amount produced in country i and sold in j. This is positive only if the firm is type-d. X_{jj} is the amount produced and sold in country j. This is positive only if the firm is type-h or v. X_{ji} is the amount produced in country j and sold in i. This is positive only if the firm is type-v.

Y_{ii} is the total amount of *Y* produced and sold in country i and similarly for Y_{jj}. Y_{ij} denotes *Y* produced in i and sold to j and Y_{ji} denotes *Y* produced in j and sold to i.

Evaluating profits under strategy d (Π^d)

Under this strategy, X_{ii} and X_{ij} are positive and X_{jj} and X_{ji} are zero.

We assume that household utility is given by a quadratic function. Then, per capita utility in country i is:

$$U_{pc,i} = \alpha * \frac{X_{ii}}{L_i} - \frac{\beta}{2} * \left(\frac{X_{ii}}{L_i}\right)^2 + \frac{Y_{ii} + Y_{ji}}{L_i} \tag{A1}$$

where α and β are positive parameters.

Total utility in country i is then

$$U_i = \alpha * X_{ii} - \frac{\beta}{2} * \frac{X_{ii}^{\;2}}{L_i} + Y_{ii} + Y_{ji} \tag{A2}$$

We assume that the price of commodity Y is 1 and that

$$Y_{ii} + Y_{ij} = \gamma * L_{Yi} \tag{A3}$$

where L_{Yi} is labor devoted to production of Y in country i. The wage rate in both countries must then be γ.

The budget constraint for households in country i is:

$$\gamma * L_i + \Pi = P_i * X_{ii} + Y_{ii} + Y_{ji} \tag{A4}$$

where P_i is the price of X in country i and Π is profits earned by the X firm from its operations in all countries.

Derivation of demand equations for X in the two countries

Maximizing (A2) subject to (A4) gives the demand curve in country i for X as

$$P_i = \alpha - \frac{\beta}{L_i} * X_{ii} \tag{A5}$$

Assuming that country j has the same utility function as country i then the demand curve in country j for X is

$$P_j = \alpha - \frac{\beta}{L_j} * \left(X_{ij}\right) \tag{A6}$$

Profits on domestic sales of X

$$\Pi_{ii} = P_i * X_{ii} - C_i * X_{ii} - G - F \quad \text{(A7)}$$

where C_i is marginal cost in country i.

Hence

$$\Pi_{ii} = \left(\alpha - \frac{\beta}{L_i} * X_{ii} \right) * X_{ii} - C_i * X_{ii} - G - F \quad \text{(A8)}$$

The firm chooses the sales level to maximize profits in its own market. Hence

$$\frac{\partial \Pi_{ii}}{\partial X_{ii}} = \alpha - \frac{2*\beta}{L_i} * X_{ii} - C_i = 0 \quad \text{(A9)}$$

Giving the supply function to the local market as

$$X_{ii} = \frac{\alpha - C_i}{2*\beta} * L_i \quad \text{(A10)}$$

Hence, substituting (A10) into (A8) we find that profits on local sales are

$$\Pi_{ii} = \left(\alpha - C_i - \frac{\beta}{L_i} * \frac{\alpha - C_i}{2*\beta} * L_i \right) * \frac{\alpha - C_i}{2*\beta} * L_i - G - F \quad \text{(A11)}$$

which simplifies to

$$\Pi_{ii} = \left(\frac{\alpha - C_i}{2} \right)^2 * \frac{L_i}{\beta} - G - F \quad \text{(A12)}$$

Profits on export sales of X

$$\Pi_{ij} = P_j * X_{ij} - \left(C_i + T_j \right) * X_{ij} \quad \text{(A13)}$$

where T_j is the rate of the tariff imposed by country j and transport costs.

Substituting (A6) into (A13) gives

$$\Pi_{ij} = \left[\alpha - \frac{\beta}{L_j} * X_{ij} \right] * X_{ij} - \left(C_i + T_j \right) * X_{ij} \quad \text{(A14)}$$

To maximize profits from sales in j, the firm puts

$$\frac{\partial \Pi_{ij}}{\partial X_{ij}} = -\frac{2*\beta}{L_j} * \left(X_{ij} \right) + \alpha - \left(C_i + T_j \right) = 0 \quad \text{(A15)}$$

This gives the supply function from i to j as

$$X_{ij} = \frac{L_j}{2*\beta} * \left[\alpha - \left(C_i + T_j \right) \right] \quad \text{(A16)}$$

Substituting (A16) into (A14)

$$\Pi_{ij} = \left[\alpha - \left(C_i + T_j\right)\right]^2 * \frac{L_j}{4*\beta} \qquad \text{(A17)}$$

Total profits for the firm if it adopts strategy d are:

$$\Pi^d = \Pi_{ii} + \Pi_{ij} \qquad \text{(A18)}$$

Substituting (A12) and (A18) into (A19)

$$\Pi^d = \left[\frac{\alpha - C_i}{2}\right]^2 * \frac{L_i}{\beta} + \left[\frac{\alpha - \left(C_i + T_j\right)}{2}\right]^2 * \frac{L_j}{\beta} - G - F \qquad \text{(A19)}$$

Evaluating profits under strategies h and v (Π^h and Π^v)

Following similar methods for strategies h and v we find that:

$$\boldsymbol{\Pi}^h = \left(\frac{\alpha - C_i}{2}\right)^2 * \frac{L_i}{\beta} + \left(\frac{\alpha - C_j}{2}\right)^2 * \frac{L_j}{\beta} - 2 * G - F \qquad \text{(A20)}$$

$$\Pi^v = \left[\frac{\alpha - \left(C_j + T_i\right)}{2}\right]^2 * \frac{L_i}{\beta} + \left[\frac{\alpha - C_j}{2}\right]^2 * \frac{L_j}{\beta} - G - F \qquad \text{(A21)}$$

Solving the Markusen model: numerical examples

Profits in the three strategies: basecase

Assume $C_i = C_j$ and $T_i = T_j$

Assume $L_i + L_j = 1$.

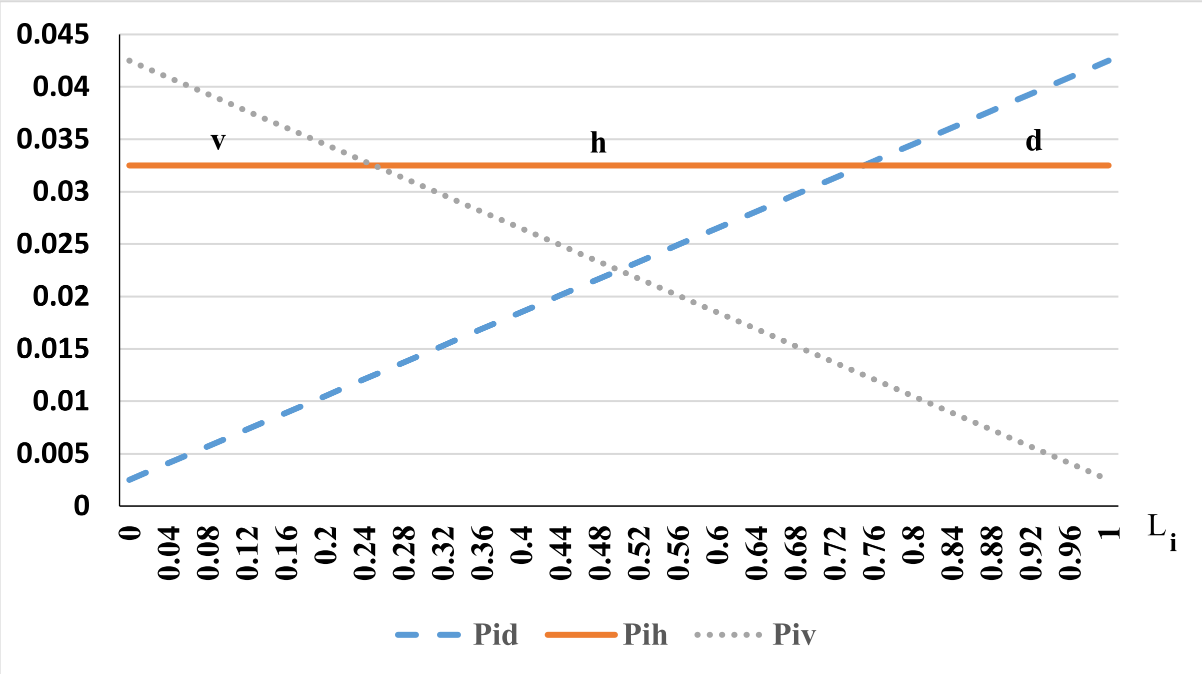
Assume $\alpha = \beta = 1$.

Assume $C_i = 0.5$.

Assume $T_i = 0.2$

Assume F = 0.01 and G = 0.01

Chart A1. Profits under the three strategies plotted as functions of L_i: basecase



Given the parameter values listed above, the dotted line in Chart A1 shows profits under strategy v. If country j is very large then the firm's profits will be high if it locates production in j, close to the large market. The dashed line shows profits under strategy d. If country i is very large then strategy d generates high profits. The solid line shows profits under strategy h. Under this strategy profits are invariant to the relative sizes of the two countries.

As shown in the chart, with the particular parameter values listed above, if country i is less than 25% of the world population then country i will undertake FDI and import its requirements of good X (strategy v).

If country i is greater than 75% of the world population then country i will do all of the production of X and export to country j (strategy d).

If country i has a population share between 25% and 75% of the world population, then country i will produce for home consumption and set up via FDI production facilities in j to meet j's requirements (strategy h).

If country j is growing rapidly in economic size, relative to i (think j = China, i= U.S.), then initially firms in country i might adopt strategy d. As j grows some firms will switch to strategy h. Eventually, when j is large enough, we might observe switches from h to v. .

Effect of reducing trade costs on the flow from i to j

Assume $C_i = C_j$

Assume $L_i+L_j = 1$.

Assume $\alpha = \beta = 1$.

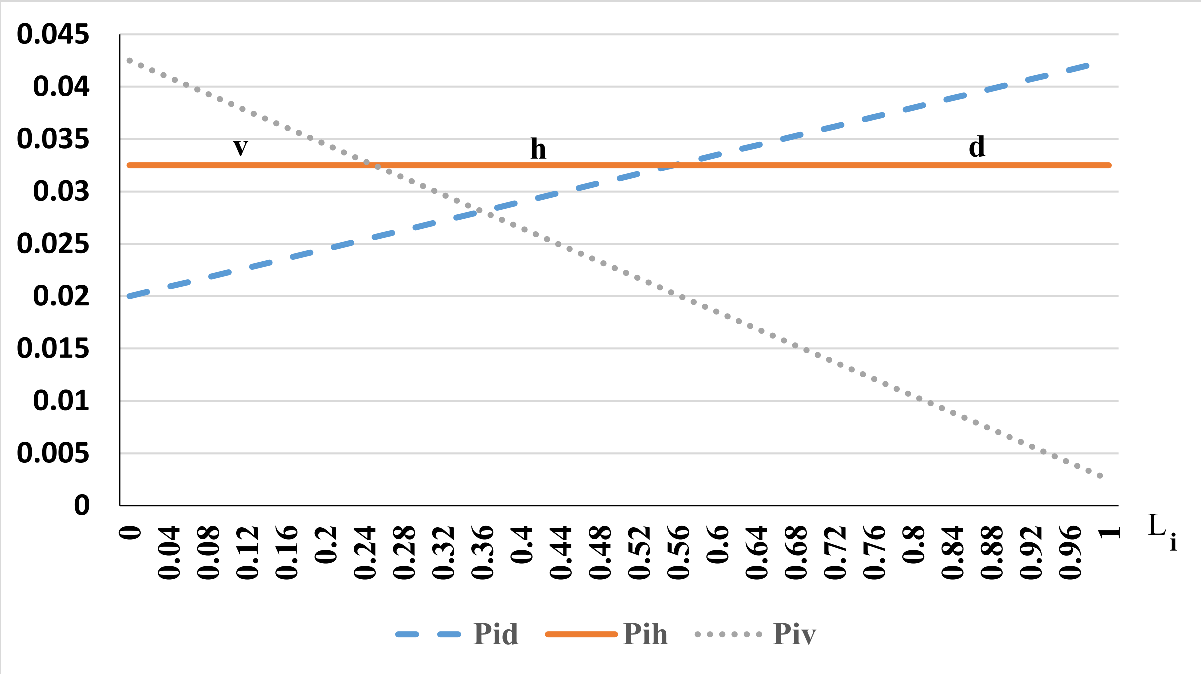
Assume $C_i = 0.5$.

Assume $T_i = 0.2$

Assume $T_j = 0.1$

Assume F = 0.01 and G = 0.01

Chart A2. Profits under the three strategies plotted as functions of L_i: reduced cost of sending X from j to i



Comparing Chart A2 with Chart A1 we see that cutting trade costs from 0.2 to 0.1 only on the flow from i to j (leaving trade costs on the flow from j to i at 0.2) strongly increases the range of population proportions in which the no FDI strategy (strategy d) applies. It reduces the range in which h applies and does not affect the range in which v applies (for v, T_j is irrelevant).

Chart A2 illustrates the temptation for country j to impose tariffs (increase in T_j) to encourage FDI, or equivalently to resist reducing tariffs.

Effect of reducing trade costs in both directions

Assume $C_i = C_j$

Assume $L_i+L_j = 1$.

Assume $\alpha = \beta = 1$.

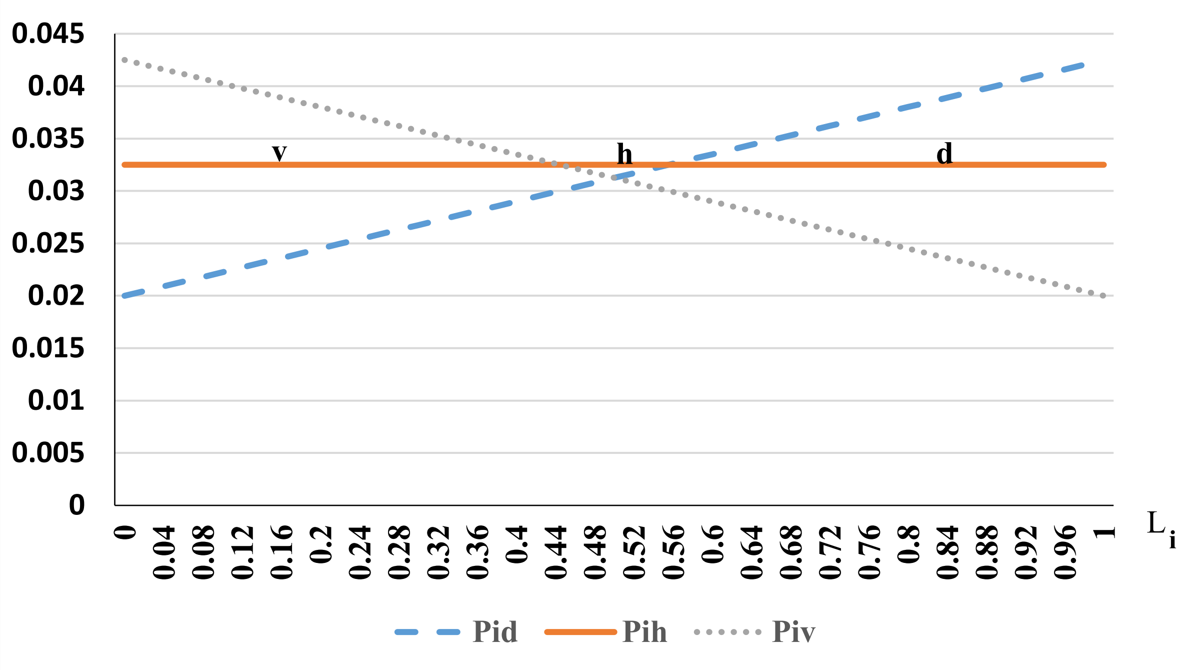
Assume $C_i = 0.5$.

Assume $T_i = 0.1$

Assume $T_j = 0.1$

Assume F = 0.01 and G = 0.01

Chart A3. Profits under the three strategies plotted as functions of L_i: reduced cost of sending X from j to i and from i to j



Now we cut trade costs from 0.2 to 0.1 on flows from j to i as well as from i to j. This increases the range for which strategy v applies. Comparing Chart A3 with Chart A2 we see further reduction in the range for which strategy h applies but there is no change in the range in which d applies. For d, reduction in trade costs on flows from j to i are irrelevant.

Chart A3 illustrates the temptation for country i to impose tariffs (increase T_i) to hold production at home (avoid strategy v, discourage FDI), or equivalently to resist reducing tariffs.

Effect of reducing production costs in country j

Assume $T_i = T_j$

Assume $L_i+L_j = 1$.

Assume $\alpha = \beta = 1$.

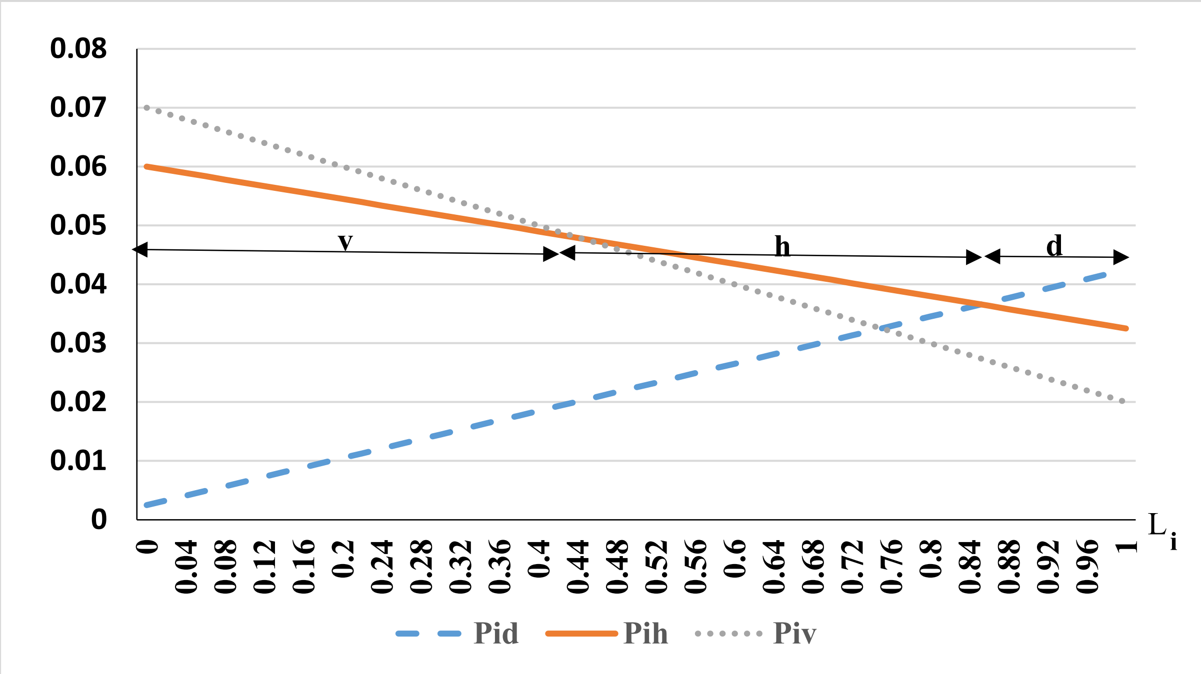
Assume $C_i = 0.5$.

Assume $C_j = 0.4$.

Assume $T_i = 0.2$

Assume F = 0.01 and G = 0.01

Chart A4. Profits under the three strategies plotted as functions of L_i: reduced cost of producing X in country j



Under strategy h the profit line is no longer horizontal: profits decrease as j becomes smaller. Compared with Chart A1, the v strategy become more likely. We think it can be proved that the d strategy becomes less likely. Hence FDI becomes more likely – more likely that production takes place in country j (a v or h strategy).

Welfare effects in the Markusen model

If strategy d applies, then $X_{ii} > 0$ and $X_{ji} = 0$. In this case welfare (utility) for country i is

$$U_i = \alpha * X_{ii} - \frac{\beta}{2} * \frac{X_{ii}^2}{L_i} + Y_{ii} + Y_{ji} \tag{A22}$$

Substituting from the budget constraint, (A4), we obtain

$$U_i = \alpha * X_{ii} - \frac{\beta}{2} * \frac{X_{ii}^2}{L_i} + \gamma * L_i + \Pi - P_i * X_{ii} \tag{A23}$$

With d applying, X_{ii} is as in (A10) and we have

$$U_i = \alpha * \frac{\alpha - C_i}{2*\beta} * L_i - \frac{\beta}{2} * \frac{\left[\frac{\alpha - C_i}{2*\beta} * L_i\right]^2}{L_i} + \gamma * L_i + \Pi^d - P_i * \frac{\alpha - C_i}{2*\beta} * L_i \tag{A24}$$

Substituting from (A19) into (A24) gives

$$U_i = \alpha * \frac{\alpha - C_i}{2} * \frac{L_i}{\beta} - \frac{1}{2} * \left[\frac{\alpha - C_i}{2}_{\,i} \right]^2 * \frac{L_i}{\beta} + \gamma * L_i$$
$$+ \left\{ \left[\frac{\alpha - C_i}{2} \right]^2 * \frac{L_i}{\beta} + \left[\frac{\alpha - (C_i + T_j)}{2} \right]^2 * \frac{L_j}{\beta} - G - F \right\} \tag{A25}$$
$$- P_i * \frac{\alpha - C_i}{2} * \frac{L_i}{\beta}$$

Aside combining (A5) and (A10)

$$P_i = \alpha - \frac{\alpha - C_i}{2} \tag{A26}$$

Substitute (A26) into (A25) to obtain

$$U_i^{\,d} = \frac{3}{2} * \left[\frac{\alpha - C_i}{2} \right]^2 * \frac{L_i}{\beta} + \left[\frac{\alpha - (C_i + T_j)}{2} \right]^2 * \frac{L_j}{\beta} + \gamma * L_i - G - F \tag{A27}$$

Following the same process we obtain

$$U_i^{\,h} = \frac{3}{2} * \left[\frac{\alpha - C_i}{2} \right]^2 * \frac{L_i}{\beta} + \left[\frac{\alpha - C_j}{2} \right]^2 * \frac{L_j}{\beta} + \gamma * L_i - 2 * G - F \tag{A28}$$

and

$$U_i^{\,v} = \frac{3}{2} * \left[\frac{\alpha - C_j - T_i}{2} \right]^2 * \frac{L_i}{\beta} + \left[\frac{\alpha - C_j}{2} \right]^2 * \frac{L_j}{\beta} + \gamma * L_i - G - F \tag{A29}$$

Is the utility function continuous?

Say the parameters are such that

$$\Pi^d = \Pi^h > \Pi^v \tag{A30}$$

That is, the firm is on the cusp of doing FDI to service the needs of country j.

With (A30) in place, (A20) and (A21) imply that

$$0 = \left[\frac{\alpha - (C_i + T_j)}{2} \right]^2 * \frac{L_j}{\beta} - \left(\frac{\alpha - C_j}{2} \right)^2 * \frac{L_j}{\beta} + G \tag{A31}$$

Now from (A27), (A28) and (A31) we obtain

$$U_i^{\,d} - U_i^{\,h} = \left[\frac{\alpha - (C_i + T_j)}{2} \right]^2 * \frac{L_j}{\beta} - \left[\frac{\alpha - C_j}{2} \right]^2 * \frac{L_j}{\beta} + G = 0 \tag{A32}$$

This means that if the firm is indifferent between going to h or staying with d, then so are the consumers in country i. The move from d to h would not affect the price that the consumers in i pay for good X. The profits of the firm would not be affected [see (A30)]. There is a balance between the cost of a new plant in country j and the saving from not having to pay trade costs in servicing the market in country j.

How about if we were on the cusp of h and v? Then,

$$\Pi^{v} = \Pi^{h} > \Pi^{d} \tag{A33}$$

With (A33) in place, (A20) and (A21) imply that

$$0 = \left(\frac{\alpha - C_i}{2}\right)^2 * \frac{L_i}{\beta} - \left[\frac{\alpha - \left(C_j + T_i\right)}{2}\right]^2 * \frac{L_i}{\beta} - G \tag{A34}$$

From (A29), (A30) and (A35) we obtain

$$U_i^h - U_i^v = \frac{3}{2} * G - G = \frac{G}{2} > 0 \tag{A35}$$

Thus, if a small parameter change switches the firm from h to v, then households in country i are worse off. There is a discontinuous drop in U_i.

Implications for welfare

The profits of the firm are a continuous function of L_i, L_j, C_i, C_j, G, F, T_i and T_j. This function is not differential at all points. For example, as can be seen from our charts, regime change (going from d to h to v) causes discontinuous changes in the slope of the profit function with respect to L_i and L_j.

The utility of households can show discontinuous jumps in response to small changes in exogenous variables when these changes cause regime switches. The utility of country k makes a discontinuous fall if a small change in an exogenous variable causes the firm to switch from satisfying demand in k by production in k to satisfying this demand by imports from the firm's plant in a country outside k. We analyzed the case for country i when the firm switches from h to v. But the statement is also true for country j when the firm switches from h to d.

The intuitive explanation is that the price paid by households in k is an increasing continuous function of marginal cost. Marginal cost for supplying via imports includes trade costs. Thus, for country k, a switch to sourcing from imports rather than from plants within country k, causes a jump in the price paid by households in k, with a consequent discontinuous fall in their utility.

We see that for country i, there is an incentive to follow policies which avoid a switch to regime v (e.g. imposing tariffs on imports from j). Similarly, there is an incentive for country j to encourage a regime switch from d to h (e.g. via subsidizing plant setup or marginal costs in country j).

A2. Comparing Markusen with the USITC approach

The starting point for GTAP-GAC3 was the work at the USITC initiated by Fukui and Lakatos (2012) and being further developed by Yuan and Tsigas (2020). We adopted the demand side of the Yuan & Tsigas model while greatly developing the supply side. On the supply side we:

- ➢ allowed dynamic endogenous adjustment of national capital stocks in each industry and region. These stocks are exogenous in Y&T's model.
- ➢ introduced an investment process for each industry and region. This means that expansion of production capital for industry j in region d will require construction and other investment-related activities in country d and finance from the owning country of the expanded capital.
- ➢ tracked the accumulation for each region of foreign assets and liabilities and related international income flows.
- ➢ specified employment-wage adjustment processes in each region so that favourable shocks such as FDI inflow lead to short-run increases in aggregate employment and long-run increases in real wage rates. Similarly, unfavourable shocks will generate short-run decreases in aggregate employment and long-run decreases in real wage rates.

In the USITC work and other Petri extensions, the emphasis is on the role of FDI in providing host countries with an enriched range of choices. This contrasts with Markusen who pays no attention to product differentiation. He concentrates on explaining when a firm will undertake FDI in response to: changes in relative sizes of markets; changes in tariff rates and other components of trade costs; and changes in production costs at home and abroad.

Our interpretation is that the USITC has adopted a pragmatic approach whereby their models can reproduce the existing situation. At the same time, with product differentiation, their models can give realistic simulation responses to changes in tariffs. Markusen's models can imply unrealistic flip-flop: sudden adjustments between regimes d, h and v when there are small changes in tariffs and other exogenous variables. What Markusen does, which is missing from the USITC approach, is provide background theory on the determinants of FDI.

An ideal approach would be to recognize that Markusen gives us a model of a single firm. Then, we would assume that there are many firms in each industry in each country with parameters drawn from various probability distributions. A change in exogenous variables would cause some but not all firms to undertake a regime switch. By setting up the probability distributions in a suitable way, we would hope to build a model in which industry responses are smooth despite discontinuous regime shifts by individual firms. However, the ideal approach was too ambitious for the present project.

While adopting the USITC paradigm we should nevertheless refer to Markusen for important insights. Perhaps the greatest difficulty in transferring Markusen theory into CGE modelling will be coping with economies of scale. For example, how should we replicate the Markusen result that growth in the Chinese market relative to the U.S. market encourages U.S. firms to service China through FDI rather than exports? Perhaps we can accompany rapid-growth scenarios for China with cost-reducing technology changes for production by U.S. firms located in China.

REFERENCES

Corong, E., T. Hertel, R. McDougall, M. Tsigas and D. van der Mensbrugghe (2017), "The standard GTAP model, version 7", *Journal of Global Economic Analysis*, vol. 4, No. 1, pp.1-119.

Dixon, P.B., M.T. Rimmer and N. Tran (2019a), "GTAP-MVH, A Model for Analysing the Worldwide Effects of Trade Policies in the Motor Vehicle Sector: Theory and Data", CoPS/IMPACT Working G-290, available at https://www.copsmodels.com/elecpapr/g-290.htm .

Dixon, P.B., M.T. Rimmer and N. Tran (2019b), "Creating a Disaggregated CGE Model for Trade Policy Analysis: GTAP-MVH", CoPS/IMPACT Working G-291, available at https://www.copsmodels.com/elecpapr/g-291.htm ;

Dixon, P.B. and M.T. Rimmer (2020), "Disaggregating employment by industry, occupation, age, education, gender, and wage rate in GTAP-GAC", *Report to Global Affairs Canada,* March 27, pp. 22, available from the authors.

Dixon, P.B. and M.T. Rimmer (2021), "Using household data in GTAP to generate income distribution and social welfare results for Canada", *Report to Global Affairs Canada,* January 26, pp. 17, available from the authors.

Fukui T. and C. Lakatos (2012), "A global database of foreign affiliate sales", *GTAP Research Memorandum No. 24,* July, pp. 46, available at https://www.gtap.agecon.purdue.edu/resources/download/6082.pdf .

Lakatos, C. and T. Fukui (2014), "Liberalization of retail services in India", *World Development*, vol 59, pp 327-40.

Markusen, J.R. (2020), *Multinational firms and the Theory of International Trade*, MIT Press, available at https://mpra.ub.uni-muenchen.de./8380/ .

Petri, P. (1997), "Foreign direct investment in a computable general equilibrium framework" in conference Making APEC Work: economic challenges and policy alternatives, available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1549616 .

Yuan, J. and M. Tsigas (2020), "An Economic Analysis of U.S. FDI in China and Mexico: A GTAP-FDI Model Perspective", Powerpoint presentation at the USITC Workshop on modelling, November 9, 2020. Also see Tsigas, M. and J. Yuan (2018), "Quantifying the Economic Impact of U.S. Offshoring Activities in China and Mexico - a GTAP-FDI Model Perspective" GTAP 2018 Conference paper, available at https://www.gtap.agecon.purdue.edu/resources/download/8971.pdf .