Expansion of trade at the extensive margin: A general gains-from-trade result and illustrative examples

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ABSTRACT

The basic gains-from-trade theorem makes a stark comparison between completely free trade and complete autarky. This paper is motivated by recent evidence that trade has greatly expanded on the extensive margin (aka fragmentation, vertical specialization, offshoring) by adding newly traded goods and services and that much of this new trade is in intermediates. I provide an extension of existing gains-from-trade results by allowing trade in an added set of final and/or intermediate goods. As seems generally understood, a sufficient condition for all countries to gain from liberalization is that the relative world prices of initially-traded goods don’t change, but I don’t think that this has been generalized to expanding the set of tradeables. Further, trade costs break the strict link between domestic and world prices in my approach and this results in interesting subtleties as initially-traded goods change their trade status following fragmentation. I illustrate these results by applying them to two recent and quite specific formulations of expansion at the extensive margin: Grossman and Rossi-Hansberg (2008) and Markusen and Venables (2007).

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1. Introduction

There has been a lot of recent interest in the expansion of trade at the extensive margin, in which innovations in communications, transportation, and institutions have permitted a wider range of goods and services to be traded. This added trade at the extensive margin goes by a variety of names including “fragmentation”, “vertical specialization”, “trade in tasks”, and “offshoring”. These added goods and services have generally been modeled as intermediates, though there is no compelling reason to make such an assumption. The basic gains-from-trade theorem which we all teach makes the stark comparison between completely free trade and complete autarky. While this is an important benchmark, no one claims that it is a very relevant comparison. Some generalizations are relatively straightforward, such as comparing restricted trade versus more liberal trade. In this latter case, requirements for gains are more demanding than in the simple free-trade versus autarky case: losses from liberalization are possible due to adverse world price changes.

The analysis and analytical tools needed to address fragmentation are rather different from those of traditional trade theory and computational analysis, in which a liberalization generates more trade in an existing set of goods and services. Applied general-equilibrium modeling has long suffered from failing to deal with trade at the extensive margin (see the critique in Kehoe (2005)). Now we must focus on discrete changes in which liberalization switches some goods and services from non-traded to traded status and indeed some previously-traded goods could become non-traded or no longer produced in some countries. In short, analytical theory has been confounded by an inability to solve for world general-equilibrium price changes and computational analysis by difficulties with “corner solutions” that are fundamental to understanding the consequences of fragmentation.

The purpose of this paper is to try to make progress in a more general approach to the gains from trade due to expansion of trade at the extensive margin. I begin with a general gains-from-trade result in which there are two sets of goods, traded and non-traded, any of which can be used as an intermediate and/or final good. There are (or

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* This paper is a significant revision of a long-stalled earlier version circulated under the title “Expansion of trade at the extensive margin: welfare and trade-volume consequences”. That version was presented at the Midwest meetings in Minneapolis, the Athens ETSG and at CESifo Munich all in 2007 and this most recent version at the University of New South Wales in 2011. The many comments I have received, particularly about older work now generally ignored, are greatly appreciated.

1 General discussions and evidence are found in Arndt and Kierzkowski (2001), Broda and Weinstein (2006), Hummels and Klenov (2005), Hummels et al. (1998, 2001), Jones (2000), and Yi (2003); Kehoe (2005) and Kehoe and Ruhl (2009) show that country pairs that undergo trade liberalization or one of the pair undergoes significant structure change show large increases in trade on the extensive margin.

2 An excellent exposition of the basic gains-from-trade proof and its limitations is found in Dixit (1985), where he notes important early contributions of Kemp (1962) and Samuelson (1962). These in turn draw from the methodologies developed by Arrow, Debreu, and McKenzie. A good exposition and review of these latter contributions can be found in several articles in Eatwell et al. (1987).
can be) trade costs on initially traded goods such that the relationship between domestic and world prices is not strictly pinned down by the latter: the domestic price differs according to whether the good is exported, imported, or non-traded. Liberalization takes the form of allowing trade in the non-traded goods. A given country may or may not start trading some of these goods, and any initially traded good may change its trade status. A contribution of the paper is thus to generalize the analysis of Dixit (1985), who rules out trade costs and determining which goods are traded in equilibrium, saying that “such a model quickly becomes too complex to yield useful results”. Thus he restricts his analysis to “an extreme case that transport costs are zero for one set of commodities and infinite for another” (both quotes, page 316).

The gains-from-trade result here shows that a sufficient condition for all countries to gain from fragmentation is that the world relative prices of the initially-traded goods do not change. This severe condition is the weakest condition for Pareto improvements in standard models with no trade costs: with any change in world prices, the sufficient condition must fail for at least one country. With trade costs, this need not be the case since domestic prices of initially-trade goods may move differently from world prices as goods change their trade status. Pareto improving gains are possible in spite of some movement in world prices.3

The sufficient conditions still seem severe and so the paper then turns to some specific cases that have been analyzed in the last couple of years. There are two quite distinct approaches to trade at the extensive margin in the theory literature. The first is when trade costs lead to an endogenous set of (typically final) non-traded goods, and then a general fall in trade costs leads to a reduction in the number of non-traded goods. This is the approach taken in Dornbusch et al. (1977), Eaton and Kortum (2002) and Melitz (2003) where an equal fall in trade costs of all consumption goods leads to a larger number of traded goods.

The second approach assumes a distinct set of initially-non-traded goods, generally intermediate goods, then some innovation permits these goods to be traded, holding the trade costs of the initially-traded goods constant (including the special case of free trade for these initially-traded goods): this is “fragmentation”. Grossman and Rossi-Hansberg (2008) and Markusen and Venables (2007) assume initially-traded final goods and no trade in intermediates. An innovation allows trade in some intermediates, final-goods trade costs held constant.

The general gains-from-trade result covers both cases in a competitive framework, but any model with increasing returns and imperfect competition such as Melitz requires much more severe restrictions to rule out losses from trade. I will comment relatively briefly on the first approach since I think it is better understood. More effort and some numerical examples will be devoted to the second approach, using modifications of Grossman and Rossi-Hansberg (2008) and Markusen and Venables (2007).

The modified examples suggest that the sufficient conditions for gains and actual (numerical) gains are likely to occur to all countries when the countries and the fragmentation itself is relatively “symmetric”. The countries are symmetric (by definition) when they are approximately the same size though differing in relative factor endowments. The fragmentation is symmetric when, for example, both a labor-intensive intermediate or task and a capital-intensive intermediate or task are both introduced into trade together. These two symmetries minimize or in the case of perfect symmetry eliminate terms-of-trade changes that violate the sufficient condition for gains. Numerical solutions in which one country loses always involve a deterioration in the terms of trade for the losing country as the general result requires, and always involves one of the two symmetries being violated. But the numerical solutions also emphasize the “sufficiency” part of the general result in that there are clear examples where a country gains in spite of a significant terms-of-trade loss.

The final section is an adaptation of Markusen and Venables (2007) in which we propose a new geometric tool to analyze problems such as fragmentation in the presence of country-specific trade costs. Our “box” is a matrix of countries, with a country’s factor endowments on one axis and a country’s trade costs on the other. Every cell in the matrix is a distinct country, and all countries trade together simultaneously. Thus not only can a capital abundant country be compared to a labor-abundant country, a high-trade-cost capital-abundant country can also be compared to a low-trade-cost capital-abundant country. The gains-from-trade result, or its violation, is nicely illustrated with this technique. Finally, all of these examples show that, due to trade costs, there are lots of cases where an initially traded final good becomes non-tradeable and this is to the benefit of that country, illustrating another important feature of the gains-from-trade result.

2. A general gains-from-trade result

There are two sets of goods, X and Y goods. X is initially traded and Y is initially non-traded. p_i and q_i denote the domestic prices for X_i and Y_i. Any X or Y good may be used as an intermediate in any other good and may have no final use. A Y good could be produced with a single primary factor and used as an intermediate in all X goods, which is a Grossman and Rossi-Hansberg (2008) “task”.

We will use a simple trade-cost formulation from Markusen and Venables (2007). Assume the usual iceberg trade costs, and conceive of each country exporting and importing from a central entrepot. Costs are paid in both directions. Let superscript w denote world prices, and let t ≥ 1 denote the (gross) trade cost to our country in question. For one unit of a good exported, 1/t arrives, so if its world price at the entrepot is p^w_i, then price received for a unit of (unmelted) exports (E) must be p^w_i/t for the value to balance (p^w_i/E) at the entrepot equals (p^w_i/E exported). Similarly, an import good’s domestic price is p^w_i. With t ≥ 1, the domestic price of an initially-tradeable X good i must fall in the interval

\[ p^w_i/t ≥ p_i ≥ p^w_i/t. \] (1)

The domestic price p_i must lie at the left-hand boundary if it is an import good, at the right-hand boundary if it is an export good, and (weakly) in between if it is a non-traded good.4

X_i and Y_i will denote the total (gross) output of these goods. The following notation is used for domestic intermediate use (of which some part might be imported X or Y).

\[
\begin{align*}
&XX_{ji} \quad \text{intermediate use of } X_i \text{ in } X_j \\
&X_j \quad \text{intermediate use of } Y_j \text{ in } X_i \\
&Y_j \quad \text{intermediate use of } Y_j \text{ in } Y_i \\
&\sum_t p_jXX_{ji} = pXX_{ji} \quad \text{value of } X \text{ intermediate use in } X_i \\
&\sum_t q_jY_{ji} = qY_{ji} \quad \text{value of } Y \text{ intermediate use in } X_i \\
&\sum_t p_jXY_{ji} = pXY_{ji} \quad \text{value of } X \text{ intermediate use in } Y_i \\
&\sum_t q_jY_{ji} = qY_{ji} \quad \text{value of } Y \text{ intermediate use in } Y_i.
\end{align*}
\]

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3 The idea that gains moving from restricted (but positive) trade to more-liberal trade require ruling out “on average” terms-of-trade losses is not new, though I don’t know who to credit (a folk theorem?). An excellent general discussion is found in Deardorff (2008) and the result is noted for trade in “tasks” in Baldwin and Robert-Nicoud (2010). A simple example of losses from liberalization: a large country that unilaterally drops its optimal tariff will be worse off due to a terms-of-trade deterioration.

4 Under the interpretation that the Y goods can be traded at the same cost t but are not traded because of this cost as in DFS, then Eq. (1) applies to the Y as well. If the Y goods face different sorts of barriers as in Grossman and Rossi-Hansberg or Markusen and Venables, then t only refers to the X goods, t may equal 1 (free trade in X goods) and may remain constant following trade in Y.

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There are \( m \) primary factors \( V \) in inelastic supply, with domestic prices \( w_i \).

\[
V_{xim} \text{ factor } m \text{ used in } X_i, \quad V_{ym} \text{ factor } m \text{ used in } Y_i
\]

\[
\sum_m w_m V_{xim} \equiv w_i V_{xm} \sum_m w_m V_{ym} \equiv w_i V_{ym}
\]

Let superscript \( n \) denote the quantity or domestic price of a good when \( Y \) goods are not traded and superscript \( f \) denote quantities and domestic prices when \( Y \) goods can be traded. \( Y \) goods can become traded either due to a fall in a country's \( t \) for all goods, \( X \) and \( Y \), or to specific innovations allowing \( Y \) to be traded, holding \( t \) constant for \( X \) goods. Profit maximization in \( X \) industry \( i \) depends on the profits for industry \( i \) at \( f \)-prices and \( f \)-quantities are (weakly) greater than the value of any other feasible set of inputs and output at \( f \)-prices: in particular, the \( n \)-quantities which are feasible by definition.

\[
p_i' X_i' - p_i' X_i' q_i' Y_i' - w_i V_i' \geq p_i X_i - p_i X_i q_i Y_i - w_i V_i
\]

(2)

\[
\text{Sum over all } i \text{ industries}
\]

\[
p_i' X_i' - p_i' X_i' q_i' Y_i' - w_i V_i' \geq p_i X_i - p_i X_i q_i Y_i - w_i V_i
\]

(3)

Similarly for \( Y \) industries.

\[
q_i' Y_i' - p_i' X_i' q_i' Y_i' - w_i V_i' \geq q_i Y_i - p_i X_i q_i Y_i - w_i V_i
\]

(4)

Add the Eqs. (3) and (4) together, noting that total primary factor usage on both sides at prices \( w \) cancels out (on both sides of the equation usage sums to the (inelastic) total supply).

\[
w_i' V_i' = w_i V_i = w_i' V_i = w_i V
\]

(5)

The sum of Eqs. (3) and (4) then simplifies to:

\[
[p_i' X_i' - p_i' X_i' q_i' Y_i' + q_i' Y_i' - p_i' X_i' q_i' Y_i'] \geq [p_i X_i' - p_i X_i' q_i' Y_i' + q_i' Y_i - p_i X_i q_i Y_i]
\]

(6)

Rearrange the terms on the right-hand side of Eq. (6)

\[
[p_i' X_i' - p_i' X_i' q_i' Y_i' + q_i' Y_i' - p_i' X_i' q_i' Y_i'] \geq [p_i X_i' - p_i X_i' q_i' Y_i' + q_i Y_i - p_i X_i q_i Y_i]
\]

(7)

The left-hand side of Eq. (7) is the value of net output in the \( f \) equilibrium and so, by the balance-of-trade constraint, is equal to the value of final consumption (subscript \( c \)) in the \( f \) equilibrium. Trade must balance at domestic prices \((p_i' = p_i' \text{ for an import or } p_i' / t \text{ for an export})\). With no tariffs, the domestic price of any initially traded good will equal the world price corrected for trade costs. For any initially non-traded good, production minus intermediate use equals consumption and so any such good cancels out of the balance-of-trade constraint at any price. The balance-of-trade constraint can thus be written in terms of domestic prices for \( Y \) goods, traded and non-traded.\(^5\) The left-hand side of Eq. (7) equals the value of consumption in the \( f \) equilibrium.

\[
[p_i' X_i' - p_i' X_i' q_i' Y_i' + q_i' Y_i' - p_i' X_i' q_i' Y_i'] = p_i' X_i' + q_i' Y_i' \equiv f
\]

(8)

\( Y \) goods are non-traded in the \( n \) equilibrium, so the second term on the right-hand side of Eq. (7) (net output of \( Y \) goods) is just the value of the consumption of \( Y \) goods in the \( n \) equilibrium evaluated at \( f \)-prices.

\[
q_i' Y_i' = [q_i' Y_i' - q_i' Y_i' - q_i' Y_i']
\]

(9)

Substitute Eqs. (8) and (9) for the relevant terms in Eq. (7), then Eq. (7) becomes

\[
[f] = [p_i X_i - p_i X_i q_i Y_i + [q_i Y_i'] + [p_i X_i'] - p_i X_i q_i Y_i + [p_i X_i']]
\]

(10)

Trade balance in the \( n \) equilibrium is given by:

\[
p_i' X_i' - p_i' X_i' q_i' Y_i' - p_i' X_i' = 0
\]

(11)

Add Eq. (11) to the right-hand side of Eq. (10), also add and subtract \( p_i' X_i' \) from the right-hand side and, Eq. (10) becomes

\[
[f] = [p_i X_i' + q_i Y_i'] + [p_i X_i' - p_i X_i' q_i Y_i' - p_i X_i'] + [p_i X_i' - p_i X_i' q_i Y_i' - p_i X_i']
\]

(12)

The first term on the right-hand side of Eq. (12) is the value of the \( n \)-equilibrium consumption at \( f \)-equilibrium prices which we can denote as:

\[
[c_i] = [p_i X_i' + q_i Y_i']
\]

(13)

Finally, note that the second and third bracketed terms on the right-hand side of Eq. (12) are net exports of \( X \) goods in the \( n \)-equilibria: total output minus domestic intermediate use minus domestic consumption. The second term values these exports at \( f \)-prices and the third term values them at \( n \)-prices. Let net exports be given by

\[
[X_i' - X_i' - X_i'] \equiv X_i' \quad k = f, n
\]

(14)

Then using Eqs. (13) and (14), Eq. (12) becomes:

\[
[f] = [c_i] + (p_i - p_i') X_i'
\]

(15)

Gains from allowing trade in \( Y \) goods make the country better off if the left-hand side of Eq. (15) exceeds the first term on the right-hand side: the value of \( f \)-equilibrium consumption at \( f \)-equilibrium prices exceeds the value of \( n \)-equilibrium consumption at \( f \)-equilibrium prices; that is, \( f \)-equilibrium consumption is revealed preferred.

Suppose that fragmentation leaves relative world prices of \( X \) goods unchanged and refer back to Eq. (1). If the fragmentation involves a reduction in the country's \( t \) (referred to as the first approach above), then the prices at which the country can trade are \( p_i > p_i' / t \) for an export good and \( p_i = p_i' / t \) for an import good where \( t \) denotes the initial value of \( t \). If the fragmentation leaves the country's trade costs for the \( X \) goods unchanged (referred to as the second approach above), then these strict inequalities become strict equalities.

Consider an initially exported good \( EX_i' > 0 \), so that its initial domestic price is equal to \( 1 / t \) times the world price: \( p_i = p_i ' / t \). with the world prices for \( X \) goods in the \( n \)-equilibrium evaluated at \( f \)-prices. \( Y \) goods are non-traded in the \( n \) equilibrium, so the second term on the right-hand side of Eq. (7) (net output of \( Y \) goods) is just the value of the consumption of \( Y \) goods in the \( n \) equilibrium evaluated at \( f \)-prices.
price held constant by assumption after trade in Y is allowed

\[ \left(p_i^f - p_i^m\right) \left(EX^f_i\right) \geq 0 \quad \text{good } i \text{ continues to be exported} \]

\[ \left(p_i^f - p_i^m\right) \left(EX^m_i\right) \geq 0 \quad \text{good } i \text{ becomes non-traded} \]

\[ \left(p_i^f - p_i^m\right) \left(EX^m_i\right) \geq 0 \quad \text{good } i \text{ switches to an import} \]

If export good i becomes non-traded or an import good, its price cannot be lower than the price at which it could be exported: \( p_i^f \geq p_i^m/t \) for \( EX^f_i > 0 \) when i switches to an import good or to non-traded status. The argument and inequalities in Eq. (16) also hold for any initially imported good: \( p_i^f \leq p_i^m = p_i^w t \) when \( EX^m_i < 0 \) initially and then switches to an export or non-traded good.

Thus for any X good, that term in the right-hand summation in Eq. (15) must be non-negative. From Eq. (15), this is in turn a sufficient condition for

\[ C^f \geq C^m \]

Trade in the \( f \)-equilibrium is revealed preferred to trade in the \( n \)-equilibrium for all countries.

General result:

A sufficient condition for adding trade in Y goods to (weakly) improve the welfare of all countries is that the world relative prices of the X goods are unchanged.

A sufficient condition for adding trade in Y goods to improve the welfare of a given country is that the value of its initial net-export vector at post-Y-trade prices is positive: \( p_i^Y \) \( EX^i_Y > 0 \) (the initial net export vector would now generate a surplus; “on average”, the terms-of-trade do not get worse). Because \( p_i^f \geq p_i^m/t \) is defined at trade-cost-adjusted domestic prices, it is possible that this condition can be satisfied for all countries, contrary to the usual case where initial trade costs \( t \) for the X goods are zero.

Again, this does not assume domestic prices are unchanged, since some goods may change their trade status or because the fragmentation is caused by a fall in the country’s trade cost \( t \).

In a formulation with two countries and zero trade costs \( t \) for the X goods, the inequality \( p_i^f - p_i^m \) \( EX^i > 0 \) cannot hold for both countries. Both price vectors must equal the world price vectors in each country, and one country’s net-export vector is equal and opposite in sign to the other country’s vector. So in fact this term has an equal and opposite value in the two countries: the sufficient condition cannot hold for one of the countries (given some \( dp_w \neq 0 \)). But it is worth noting that this need not be the case in the presence of trade costs and we will see the relevance later in the paper. Suppose that good i is initially exported from country e and imported in country m, and that each country has the same initial trade costs, so the initial price relationships are

\[ p_i^e = p_i^m/t \rightarrow p_i^e t = p_i^m. \]

If the good becomes non-traded or if the fragmentation is due to a fall in each country’s initial trade cost \( t \), the (initial) exporter’s domestic price can rise \( p_i^e > p_i^m \) and the importer’s price can fall \( p_i^m < p_i^m \); the sufficient condition in Eq. (15) can hold as a strict inequality for both countries even if \( dp_w \neq 0 \). With reference to the inequalities in Eq. (1), the importer’s price moves in from the left-hand boundary and the exporter’s price moves in from the right-hand boundary.


As just noted, the general result holds when the expansion of trade at the extensive margin is due to a general fall in a country’s trade costs. Because they are well known and highly-cited, I’ll comment very briefly on this in relation to three papers. Dornbusch et al. (1977) have a model with a continuum of final consumption goods, and a given country will general have a subset of goods that are non-traded (in the presence of trade costs) where that country has neither a strong comparative advantage nor strong disadvantage. A fall in trade costs shrinks the number of non-traded goods, which is expansion of trade at the extensive margin. The result derived above covers this case: the added set of tradeables is the result of a fall in the country’s initial value of \( t \) and in a symmetric model the prices of a country’s initially-exported goods should rise and those of its initially-imported goods should fall with world prices constant.

Eaton and Kortum (EK) is a major development beyond Dornbusch, Fischer and Samuelson that allows for a multi-country analysis. They derive an expression for the share of country’s consumption that is spent on goods from each country, including the share spent on its own goods (their Eq. (10)). By considering symmetric countries in this equation, it is clear that the set of goods that a country produces is larger than the set it exports, but that these two converge as trade costs go to zero: the set of non-trade goods falls as trade costs fall. In a symmetric model, the prices of a country’s initially-imported goods should fall, and those of the initially-exported goods should rise as in DPS.

Melitz’s model has a continuum of final, differentiated goods produced with increasing returns to scale under monopolistic competition. While the goods are symmetric from the consumer’s point of view, firms are differentiated by their productivities. The set of export goods among goods initially produced is determined by an upper “cutoff condition” whereby firms with productivities greater than a critical level export while those below this level serve only the domestic market. A lower cutoff condition sets the boundary between domestic firms and firms that don’t enter. A fall in trade costs, at least in a symmetric model, will move the exporting cutoff down: some firms that produced non-tradeables now export. But some firms that produced non-tradeables for domestic sales only will exit and their products will be replaced by cheaper symmetric products imported from the newly-exporting foreign firms. In a symmetric model, the initially-exported goods prices should rise and the initially-imported goods should go down in price.

However, I do need to add one caveat here: any model with imperfect competition and increasing returns is not a straightforward generalization of the analysis here. Even assuming a convex production set (a big assumption), the price hyperplane is not supporting to the production set, so the inequality in Eq. (2) need not hold. Production efficiency cannot be assumed under any form of imperfect competition, a frustrating problem for gains-from-trade proofs which I worked on years ago (Markusen, 1981; Markusen and Melvin, 1984).

4. Trade costs for initially-trade goods constant: example 1, based on Grossman and Rossi-Hansberg (2008)

I now turn to the case where there are specific innovations that allow a new set of goods to be trade with the costs of initially-traded goods constant (including possibly free trade in these goods). The first specific case I will show is a much-simplified version of Grossman and Rossi-Hansberg (2008) (GRH). Table 1 shows the structure and calibration for this example and also for the Markusen and Venables (2007) example discussed below. In both cases, there are two final goods, \( X_1 \) and \( X_2 \) that produce utility, and two primary factors, L and K which themselves are non-traded.
In the GRH example, $L$ is (endogenously) divided into two tasks, labeled $TL_1$ and $TL_2$ and similarly for $K$. All goods require all tasks, a particular good requires $TK_1$ and $TK_2$ in identical amounts with no substitution between them, and similarly for tasks $TL_1$ and $TL_2$. Where the final goods $X_1$ and $X_2$ differ is in the amounts of labor versus capital tasks, and $X_1$ is assumed capital intensive. $X_1$ requires 60 each of both $TK_1$ and $TK_2$ and 40 each of both $TL_1$ and $TL_2$. $X_2$ is the symmetric mirror image, requiring 40 each of $TK_1$ and $TK_2$ and 60 each of $TL_1$ and $TL_2$.

The benchmark is that goods $X_1$ and $X_2$ can be traded while none of the tasks can be traded initially. I assume in the simulations that there are trade costs of five percent ($t = 1.05$) initially, partly to break factor-price equalization for similar countries. I assume that there is an elasticity of substitution of 1.0 between $K$ and $L$ nests for both goods and utility is Cobb–Douglas as well. Countries can differ in relative and/or absolute factor endowments. Here, I present just one simple case: an earlier version of the paper computes a series of outcomes over a world Edgeworth box and is available on request. The model is solved with GAMS, whose non-linear complementarity solver is extremely robust to corner solutions.

Denoting the two countries as $h$ and $f$, the top rows of Table 2 gives the shares of country $h$ in the total world endowment: $h$'s capital share is fixed at 0.1 and its labor share varies over the columns as shown. Two cases are presented for the GRH model. In the first, task $L_1$ becomes costlessly tradable. In the second case, task $L_1$ and $K_1$ are tradable, which could be termed a "symmetric" fragmentation due to the symmetry shown in Table 1. Both cases illustrate the analytical result above: a fall in country $h$'s relative export price is a necessary, but not sufficient condition for welfare losses relative to trade in final goods only.

Disentangling multiple general-equilibrium effects is difficult. In both GRH cases, the explanation for the points of terms-of-trade losses for country $h$ in Table 2 lies in the fact that it is smaller than country $f$.

### Table 1
Initial calibrations for illustrative examples based on Grossman Rossi-Hansberg and Markusen Venables.

| Calibration for both models: |
| Labor endowment = 200 |
| Capital endowment = 200 |

<table>
<thead>
<tr>
<th>Grossman Rossi-Hansberg</th>
<th>Final good</th>
<th>Final good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task</td>
<td>Labor</td>
<td>Capital</td>
</tr>
<tr>
<td>$L_1$</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>$L_2$</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>$K_1$</td>
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</tr>
<tr>
<td>$K_2$</td>
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<thead>
<tr>
<th>Markusen Venables</th>
<th>Final good</th>
<th>Final good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate</td>
<td>Labor</td>
<td>Capital</td>
</tr>
<tr>
<td>$A$</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>$B$</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>$C$</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

### Table 2
Terms-of-trade loss as a necessary but not sufficient condition for welfare losses: initially no trade in intermediates/tasks.

| Country $h$'s share of world capital | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Country $h$'s share of world labor | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |

#### Grossman Rossi-Hansberg

| Task $L_1$ traded (asymmetric fragmentation) | pro. change in: |
| welfare | 0.144 | 0.129 | -0.020 | -0.044 | 0.098 |
| domestic price of the export good* | 0.014 | -0.017 | -0.106 | -0.103 | 0.201 |

| Task $L_1$ and $K_1$ traded (symmetric fragmentation) | pro. change in: |
| welfare | 0.162 | 0.189 | 0.124 | 0.127 | 0.229 |
| domestic price of the export good* | -0.002 | -0.038 | -0.131 | -0.137 | 0.000 |

#### Markusen Venables

| Intermediate $C$ traded (asymmetric fragmentation) | pro. change in: |
| welfare | 0.187 | 0.004 | -0.129 | -0.171 | -0.047 |
| domestic price of the export good* | -0.068 | -0.166 | -0.241 | -0.313 | -0.092 |

| Intermediate $A, C$ traded (symmetric fragmentation) | pro. change in: |
| welfare | 0.187 | 0.004 | -0.129 | -0.130 | 0.024 |
| domestic price of the export good* | -0.068 | -0.166 | -0.241 | -0.243 | 0.050 |

*This is the change in the domestic price of the initially exported good. It diverges from the world price and world-price change if the export good becomes non-traded or imported after fragmentation.
except in the right-hand column, when the two countries are mirror images. Country $h$ is specialized in $X_2$ before task trade, and the world price of $X_2$ is higher than in an integrated world equilibrium (the relative price ratio is one in the latter, as should be clear from the symmetry in Table 1). The opening of trade in tasks moves the countries toward the integrated world equilibrium, which is a terms-of-trade deterioration for the smaller country. However, there is also a strong income effect for labor-scarce country $f$ when $L_1$ becomes traded (the marginal product of $L$ is greater in $f$ than in $h$), which shows up in the right-hand column of Table 2 as resulting in a 0.201 proportional improvement in country $h$’s terms of trade as country $f$ seeks to expand trade more.

When both $L_1$ and $K_1$ can be traded in GRH and the countries themselves are also symmetric in the right-hand column of Table 2, there is no change in the terms of trade. Symmetry with respect to both the newly-traded goods and the countries (size and relative endowments) leads to no change in world prices and all countries gain.

5. Trade costs for initially-traded goods constant: example 2, based on Markusen and Venables (2007)

A second example is a significant modification of Markusen and Venables (2007). Again, we start with a $2 \times 2 \times 2$ Heckscher–Ohlin world, but intermediates are added. The model is outlined in the lower part of Table 1, where there are three symmetric intermediate goods $A$, $B$, and $C$. As in GRH, these are pure intermediates and not used in final consumption. $A$ is the most capital intensive and is used in $X_1$, $B$ is in the middle and is used in both $X_1$ and $X_2$, and $C$ is the most labor intensive and is used only in good $X_2$. At benchmark prices of one (countries identical), the capital/labor ratios in $A$, $B$, and $C$ are 70/30, 50/50 and 30/70. Embodied factor intensities in $X_1$ and $X_2$ are 60/40 and 40/60 to correspond to the GRH example.

The numerical model uses the same total factor endowments and preferences as GRH and Cobb–Douglas substitution is used in the upper nest (between intermediate goods) in both this section and the previous one. Trade costs for final goods are 5% as in the previous section. So the two treatments are very similar except for the structure of intermediates. Experiments similar to those for GRH are shown in the low part of Table 2. The first experiment is fragmentation in which free trade in $C$ is added to the benchmark of trade in $X_1$ and $X_2$ only.

The results for MV in Table 2 when trade in $C$ is allowed are qualitatively similar to GRH when trade in $L_1$ is allowed. The points of welfare losses in both cases are associated with a terms-of-trade deterioration as the general result requires. Again, the simulations indicate and emphasize that the general result is a sufficient condition, in that there are a couple points of terms-of-trade deterioration in which welfare nevertheless increases.

The bottom rows of Table 2 allow trade in both $A$ and $C$ intermediates in MV, a symmetric fragmentation analogous to $L_1$ and $K_1$ traded in GRH, with the countries asymmetric in size and in relative endowments (as in GRH) except in the right-hand column. Points of welfare loss for country $h$ are necessarily associated with adverse changes in the prices of the initially-traded goods. The results in the right-hand column, when the countries are symmetric, of the MV model with $A$ and $C$ trade related to our earlier discussion in Section 2. The price of country $h$’s export good rises and that of country $f$ must as well, since both the countries and the newly traded goods are symmetric. The explanation is that goods $X_1$ and $X_2$ become non-traded, the traded intermediates fully displace trade in final goods. The switch to non-traded status equalizes the relative prices of final goods to unity in both countries. Thus, due to the trade costs for final goods, the relative domestic price of the initial export good rises in both countries, a possibility that I noted in the theory section. When the fragmentation and the countries are symmetric, relative world prices don’t change and all countries gain.

6. An extension to a multi-country case

A well-understood limitation of the world Edgeworth or Dixit and Norman (1980) box technique is that it is limited to two countries. There is no sense in which there can be high trade-cost countries and low trade-cost countries. This section presents a multi-country generalization based again on Markusen and Venables (2007). The structure of production is the same as in the previous section. There are two final goods, $X_1$ and $X_2$, and three intermediate goods: $A$, $B$, and $C$. $A$ and $B$ are inputs into $X_1$ production and $B$ and $C$ are inputs into $X_2$ production. Factor intensity differences are a little larger than in the previous section: capital/labor ratios in $A$, $B$, and $C$ are 80/20, 50/50 and 20/80, but all other features of the MV example of the previous section and Table 1 are preserved.

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Table 3
World prices of $p_1$, $p_2$, $p_3$, and $p_4$ in the multi-country fragmentation example fragmenta-
tion example. (For reference, $p_4$ is the domestic price of $B$ in the central ($K/L = 1$) zero-
trade-cost country.)

<table>
<thead>
<tr>
<th>Type</th>
<th>$P_1$</th>
<th>$P_2$</th>
<th>$P_3$</th>
<th>$P_4$</th>
<th>$P_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade in $X_1$ and $X_2$ only</td>
<td>1.000</td>
<td>1.000</td>
<td></td>
<td></td>
<td>1.000</td>
</tr>
<tr>
<td>Add trade in $X_1$ and $X_2$</td>
<td>1.000</td>
<td>1.000</td>
<td>0.852</td>
<td>0.852</td>
<td>1.000</td>
</tr>
<tr>
<td>Add trade in $X_1$ and $X_3$</td>
<td>1.000</td>
<td>0.797</td>
<td>0.629</td>
<td>0.629</td>
<td>1.000</td>
</tr>
</tbody>
</table>

The consumer price index $e(p_1, p_2)$ in the central ($K/L = 1$) zero-trade-cost country is the numeraire.

Thus all numbers shown are also the domestic prices of this central, free-trade country. All prices are World prices $p^w$ except $p_4$, which is not traded in any of the scenarios.

There are many countries all of which trade together simultaneously, with each country identified by a double index, one referring to the country’s endowment ratio and one referring to its country-specific trade cost ($c$ to and from the entrepot). Countries’ endowments are evenly and symmetrically distributed along a line, with the most capital abundant country having endowments $K = 0.90$, $L = 0.10$, and the most labor abundant country having endowments $K = 0.10$, $L = 0.90$. There are an odd number of countries with the central country having an endowment $K = 0.50$, $L = 0.50$. A country’s endowment is indexed by $j$.

Trade costs are country specific and apply to imports and exports from/to all countries. We could think of trade costs as being port costs only. The marginal cost of added distance is zero. Bilateral trade flows will thus not be determined, a limitation of the model. In addition to an endowment index $j$, a country has a trade-cost index $i$, which is common to all imports and exports. There are exactly $i$ countries with endowment index $j$ and $j$ countries with trade-cost index $i$. Our countries form an $i \times j$ matrix, with exactly one country in each cell of the matrix. Unlike the world Edgeworth-box approach, all countries trade at once.

We assume that the final goods $X_1$ and $X_2$ are always tradable at a country’s country-specific trade cost. None, some, or all of the intermediates may be tradable, at each country’s country-specific trade cost depending on the experiment. Primary factors are not tradable as noted above. Referring back to the notion of asymmetries, in our example here there is essentially no asymmetry due to country size, since all countries will be a quite small share of the world endowment. But there can be asymmetries in the fragmentation itself in the sense that it is biased toward one kind of gain. In the present case, allowing trade in $B$, trade in $A$ and $C$, or trade in $B$, $A$, and $C$ are neutral or symmetric fragmentations. Allowing trade in $C$ but not in $A$ and $B$ is asymmetric fragmentation. As your intuition will likely suggest, the latter will increase the efficiency of $X_2$ production and will lower the price of $X_2$ relative to $X_1$ in equilibrium.

Fig. 1 shows the experiment in which $A$ and $C$ become traded at each country’s country-specific trade cost, shown on the axis running front to back. Each cell of the Figure is a country with most capital abundant countries at the left and highest-trade-cost countries in the front; the back row of Fig. 1 is a row of countries with zero trade costs (the view from this angle is better). The vertical axis plots the proportional welfare gains over trade in $X_1$ and $X_2$ only (not autarky). There are countries in the front middle (high-trade costs, near average endowments) that have zero gains because they do not trade before or after the liberalization or innovation that allows trade in $A$ and $C$. The big gainers are the fringe countries in terms of endowments: either they stop producing $B$ and specialize in $A$ or $C$ only (low-trade-cost fringe) or they leave autarky and stop producing intermediate goods $A$ or $C$ (high-trade-cost fringe), importing their disadvantaged intermediate to combine with domestic good $B$. But interestingly, the central countries at/near the world average endowment ratio and low trade costs gain.

The reasons for this are indicated in Table 3, where the price index of the zero-trade-cost country with the average world endowment is used as the numeraire. When trade in $A$ and $C$ are allowed, fringe countries want to specialize more or completely in $A$ or $C$, while the central countries have no incentive to specialize more in $B$ at initial world prices. So it is basically a supply–demand issue: at initial relative prices $p_1/p_2 = p_3/p_4$, there is excess supply of $A$ and $C$ and so their prices must fall relative to $B$ to re-establish equilibrium. Table 3 notes that, while the relative prices of final goods don’t change, the world price of $A$ and $C$ fall relative to $B$, which makes the central countries better off.

No one loses in this symmetric example as the general result suggests: relative world prices of $X_1$ and $X_2$ don’t change. A few low-trade-cost countries have zero gains/losses, and these are countries which were well suited to integrated $X_1$ or $X_2$ production initially, and remain exporters of one final good and importers of the other after trade in $A$ and $C$ is allowed.

Fig. 2 shows the welfare gains from allowing trade in $C$ (no trade in $A$ or $B$) relative to trade in $X_1$ and $X_2$ only. $C$ is the most labor-intensive intermediate and this is an opportunity for the labor-abundant countries. The supply to the world market of $C$ by these countries pushes down the relative price of $X_2$ and $C$ has a price below that of $X_2$, though its prefragmentation world price is not defined. Prices are shown in Table 3. Fig. 2 shows that the most labor intensive countries are significant gainers. They become specialized in $C$ and their domestic prices for $C$ rise. Note that these countries are significant gainers in spite of the fact that the relative price of their initial export good $X_2$ falls. $X_2$ switches from being their export good to being non-traded or even imported.

The countries that experience losses are moderately labor-abundant countries, who produce and export good $X_2$ before and after the ability to trade $C$. The relative price of their initial export good falls, violating our sufficient condition, but they cannot escape this by switching to specializing in and exporting $C$. They experience losses as indicated in the “basin of welfare losses” area of Fig. 2.

This multi-country, multi-good model with country-specific trade costs can be applied to many other questions. One brief example may be in order. Fig. 3 shows the addition volume of trade for each country as a share of initial income when trade in $A$ and $C$ are added to trade in $X_1$ and $X_2$. For good viewing, Fig. 3 has the low-trade-cost countries in the front, the opposite to Figs. 1 and 2. Note that fragmentation reduces the volume of trade for many countries. The moderately labor-abundant countries on the center-right of Fig. 3, for example, are specialized in $X_2$, before fragmentation, but they are not bad at producing $B$, just bad at $A$. For them, trade in $A$ allows them to shift resources to $B$, which is combined with their $C$ to produce (a lesser amount of) $X_2$, and the added $B$ is combined with imported $A$ to now produce $X_1$ at home. A smaller volume of $X_2$ exports pays for the imports of just $A$ rather than having to import $X_1$ (an $A$ and $B$ bundle). The equilibrium volume of trade falls for these countries, yet most of them strictly gain and none are worse off.

Note that this example also implies that liberalization can lead to big shifts in the composition of a country’s trade, with initially-non-traded goods capturing a big part of the increase in trade volume and initially-traded goods falling in their trade shares and possibly falling in absolute trade volumes. This is consistent with the empirical findings in Kehoe (2005) and Kehoe and Ruhl (2009) who find many examples where initially-non-traded goods capture a big share of trade following liberalization or structural change while initially-highly-traded good lose significantly in trade shares.

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6 The numerical model uses the GAMS MCP solver to solve 36,863 non-linear ine-
qualities in the same number of complementary non-negative variables. The code uses
GAMS’s outstanding set features and fits onto a few pages. Code from this and
the previous sections available on request.

7 The “plateau” in the back left region of Fig. 2 is an area of welfare gains. These
countries export $X_1$ before and after trade in $C$ is allowed. They all get an equal
terms-of-trade gain as $p_1/p_2$ rises (shown in Table 3).
7. Summary

The purpose of this paper is to identify some general principles about the welfare effects of adding newly-traded goods and services to an existing set of traded goods. In my view, the existing theory literature is not very satisfactory on this, often because the tools applied do not allow the researcher to solve for world general equilibrium and world prices after fragmentation is allowed. Here I derive a general gains-from-trade result that gives benchmark sufficient conditions for added trade to be beneficial to one country or to all countries together. While this result has clear antecedents in the literature concerning going from partially liberal trade to more liberalized trade, an important innovation here is to add trade costs which allow domestic and world prices to differ and which allow some of the existing set of traded or tradable goods to move in and out of a country’s trade vector following a liberalization.

Two specific examples are then examined which are simplifications and modifications of two recent papers, Grossman and Rossi-Hansberg (2008) and Markusen and Venables (2007). In both cases, results are consistent with the central result: a necessary condition for a country to lose is that it experiences a weighted adverse price change for its initially traded goods. At the same time, the sufficiency part of the general

![Fig. 2. Additional gains from allowing trade in C (no trade in A or B).](image1)

![Fig. 3. Additional volume of trade from allowing trade in A and C (no trade in B).](image2)

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result is emphasized: there are many cases in which a country gains substantially in spite of the sufficient condition failing. The role of trade costs, which imply that initially-traded goods often change trade status, is also illustrated and found to be important in these examples; for example, a country may stop importing an expensive good and only import the fragment of it that is costly to produce at home.

Results suggest that gains are likely to occur to all countries when the countries and the fragmentation itself is relatively “symmetric.” The countries are symmetric (by definition) when they are approximately the same size. The fragmentation is symmetric when, for example, both a labor-intensive intermediate or task and a capital-intensive intermediate or task are both introduced into trade together. These two symmetries minimize or even eliminate terms-of-trade changes that violate the sufficient condition for gains.

References


