A Ricardian factor content characterization of the gains from trade: the case of 19th century Japan

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Abstract

We show that an economy's factor content of trade can serve as a “sufficient statistic” for causal inference about the existence, magnitude and sources of the gains from trade. An attractive feature of this characterization is that it imposes little structure and no parametric assumptions on the economy. We apply this measure to an unprecedented data set on product and task-specific factor employments of traded goods in 19th century pre-industrial Japan. We indentify positive gains from trade and find that Japan's gains stemmed primarily from Ricardian augmentation of its female labour force. Our historical analysis provides a unique insight into the resource reallocations resulting from international trade between economies that were technologically separated by the industrial revolution.

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1. Introduction

18th century rule for the gains from trade: “It pays to import commodities from abroad whenever they can be obtained in exchange for exports at a smaller real cost than their production at home would entail” Viner (1937, p. 440)

This paper shows that information on the factor content of trade allows us to make inferences about the existence, magnitude and sources of an economy's gains from trade. An attractive feature of the factor content characterization of trade is that it imposes little structure and imposes no parametric assumptions on the economy and its trading partners. We apply this measure to a unique historical data set on product and task-specific factor requirements of 19th century Japan and its trading partners at the time of the economy's port openings following 200 years of self-imposed isolation. We provide causal evidence of gains from trade and find that Japan's gains from trade stemmed primarily from Ricardian augmentation of its female labour force. Our historical-empirical analysis provides unique insights into the reallocation of resources that resulted from international trade between economies that were technologically separated by the industrial revolution.

The argument about the gains from trade is at the heart of international economics and since it is closely linked to whether competitive market forces allocate resources in the “right direction,” it is also at the core of our discipline. Three fundamental questions arise: Are there gains from trade? How do we measure the gains from trade? Where do the gains come from? Since our paper addresses all three questions, we use them as an organizing principle to highlighting our paper’s main contributions.

The existence question is about causality and empirical refutability. The theoretical literature has addressed the issue of causality by the comparison of an economy with and without international trade. The three core models in the field of international trade—Deardorff (1980)’s general model of comparative advantage, Krugman (1979)’s monopolistic competition model and
Melitz (2003)’s firm selection model—have identified alternative theoretical mechanisms underlying the gains from trade. The new trade theory poses a challenge for empirical refutability, since it imposes fairly restrictive assumptions on both the symmetry of consumer preferences and the functional form of the utility functions. As a result, important contributors to the literature such as Broda and Weinstein (2006) and Feenstra and Kee (2008) have focused on providing valuable estimates of the magnitude of the gains from trade that are conditional on these assumptions rather than identifying empirical test conditions for the existence of the gains.3

An attractive feature of comparative advantage trade theory is that the gains can be formulated under very general conditions. Specifically, we propose a factor content formulation that characterizes international trade as an exchange of factor services within a cost-benefit framework. The costs from trade are the resources embodied in a country’s total exports; the benefits are the counterfactual resources that would have been required to produce the foreign imports domestically. An advantage of this formulation is that the gains from trade become an empirically refutable proposition. Since the data could reveal that the costs of exports exceed the benefits from imports, this formulation allows for the possibility that competitive markets allocate resources in the wrong direction.

Following Samuelson’s classic 1939 paper (see Samuelson (1939)), existing measures of the gains from trade are rooted in consumer theory and the notion of a representative consumer. The standard gains from trade formulations compare expenditures on an economy's consumption vectors under autarky and free trade employing (autarky or free trade) goods prices to construct equivalent or compensating variation measures of the gains from trade. A shortcoming of these

3 In an insightful paper, Arkolakis, Costinot and Rodriguez-Clare (2009) have shown that if one is willing to put enough structure on the economies, the aggregate gains from trade can be inferred from two macro level statistics: an economy's income penetration ratio and the elasticity of imports with respect to variable trade costs. Their key insight is that this inference is invariant to the specific mechanism.
formulations is that the required data are rarely observed. Our formulation also compares consumption under autarky and trade. Instead of focusing on the (money) expenditures on consumption, our welfare characterization focuses on the comparison of resources necessary to attain the consumption vectors available under autarky and free trade. Gains from trade are measured by the augmentation of domestic resources that occurs through international trade. The more that domestic resources would need to be augmented to attain free trade consumption in the absence of trade, the greater are the gains from trade. A key feature of this characterization is that an economy’s factor content of trade contains all of the relevant information necessary to calculate the gains from trade; the factor content of trade thus serves as a “sufficient statistic” for a precise welfare statement without imposing any restrictions on the demand side of the economy.  

An attractive aspect of the factor content formulation is that it provides information on both the magnitude and the sources of the gains from trade. If the gains stem from differences in endowments, as suggested by the Heckscher-Ohlin model, the factor content of trade should reveal a factor trade-off; the economy experiences an increase in some factors at the cost of giving up some others. If the technological differences are the source of gains, the factor augmentation is expected to be characterized by an increase in all factors. By being able to identify the composition of the factor augmentation, the factor content approach provides a glimpse into the underlying reallocation of resources that underlies the aggregate gains from trade.

4 Chetty (2009) provides an excellent survey of the 'sufficient statistic approach' for welfare statements in the public economics literature. We are aware of two applications in the trade literature. As mentioned in footnote 3, Arkolakis, Costinot and Rodriguez-Clare (2009) identify two macro-level 'sufficient statistics' to estimate the gains from trade. However, these estimates are based on strong symmetry assumptions and functional forms on consumer utility and import demand systems. Bernhofen and Brown (2005) use autarky goods prices as a sufficient statistic for estimating comparative advantage gains from trade. But the latter paper also requires the assumption of a representative consumer who follows the weak axiom of revealed preferences.
Although our framework has the potential for a wide domain of empirical applications, we apply it to an unprecedented data set on product-specific factor employments in 19th century Japan. As argued in Bernhofen and Brown (2004, 2005), the opening up of Japan to international trade provides an exceptional opportunity to observe a market-based economy with and without international trade. Because of the limited technological change during the first decades after the economy's opening up, we can justifiably calculate and trace the economy's factor content of trade during a 10 year “experimental window” that employs a single factor employment matrix. In addition, since Japan by-and-large imported goods that were very close substitutes to domestically produced goods, we are able to calculate the factor requirements that would have been necessary to produce the imported goods with domestic production techniques. As mentioned earlier, our approach allows us to quantify the relative importance of technological differences and factor exchange in Japan’s overall gains from trade. Although we find a role for both technological differences and factor exchange in all trading years, technological differences account for the bulk of estimated gains for the sample period.

Sections 2.1 and 2.2 develop an alternative to the income-equivalent approach introduced by Samuelson (1939). The approach focuses on the gains in factors necessary to support free trade consumption. Although this formulation of the gains from trade represents a departure from the recent literature, it actually builds on what Viner (1937, p. 440) calls “the eighteenth-century rule” for the gains from trade: “it pays to import commodities from abroad whenever they can be obtained in exchange for exports at a smaller real cost than their production at home would entail.” Recent reappraisals of Ricardo (1817) by Ruffin (2002) and Maneschi (2004) suggest a link between this eighteenth-century view of “real cost” and Ricardo’s famous formulation of comparative advantage in terms labour value in the early nineteenth century. Section 2.3 provides an illustration of this link within the context of a simple Ricardian model with two goods and one factor (labour). Section 2.4 extends Ricardo’s formulation to a general equilibrium setting with
multiple factors of production and goods. The extension employs Deardorff and Staiger (1988)’s concept of “an equivalent autarky equilibrium,” which is defined as an autarky equilibrium constructed by changing factor endowments such that free trade consumption can be obtained.\textsuperscript{5} Section 3 employs the alternative formulation to provide estimates of the gains to Japan during a sample period encompassing much of the first two decades following the opening up of trade in 1859. Section 4 concludes the paper.

2. A factor content characterization of the welfare effects of trade

To put our new characterization of the welfare effects of trade into perspective, we start out by briefly reviewing the existing consumer based measures of the gains from trade. We then introduce our factor content characterization and illustrate it in different theoretical settings.

2.1 Samuelson’s gains from trade formulation

Our current neoclassical characterization of the gains from trade is rooted in Samuelson’s seminal 1939 paper. In that paper Samuelson theoretically proved the existence of the gains from trade and also linked the gains from trade characterization to the weak axiom of revealed preference.\textsuperscript{6} Since then the standard characterization of the gains from trade involves a welfare comparison of the consumption level of a representative consumer under autarky and trade.\textsuperscript{7}

\textsuperscript{5} Deardorff and Staiger (1988) use the concept of an “autarky equivalent equilibrium” to show that the factor content of trade can be used to reveal the effects of trade on relative factor prices.
\textsuperscript{6} Samuelson (1939)’s gains from trade article follows up on Samuelson (1938), which introduces the concept of the weak axiom of revealed preference. This axiom allows for the formulation of the theory of demand without relying on the concept of utility. Subsequent papers by Samuelson (1962) and Kemp (1962) extend the gains from trade argument to the case where an economy is large enough to influence the terms of trade.
\textsuperscript{7} By taking consumption as the primitive, we focus on the revealed preference approach to consumer demand which corresponds to the Slutsky income characterization of a welfare change. Alternatively, one could take utility as the primitive which corresponds to the Hicksian income characterization of a change in welfare.
Consider a small competitive economy that produces $n$ goods under autarky and trade. The autarky equilibrium is characterized by an $n$-vector of autarky prices $p^a$ and an $n$-vector of consumption $C^a$. The free trade equilibrium is given by $n$-vectors of prices $p^t$ and consumption $C^t$. Samuelson (1939) showed that competitive producer behaviour and balanced trade imply that $p^tC^t \geq p^aC^a$. The consumption welfare measures of the gains from trade can then be thought of as capturing “the distance” between $C^a$ and $C^t$ in expenditure equivalents. Using free trade prices $p^t$ as the evaluation criterion gives the Slutsky compensating variation measure of the gains from trade:

$$\Delta I^{CV} = p^tC^t - p^tC^a.$$  

(1)

$\Delta I^{CV}$ is interpreted as the change in income necessary to compensate the representative consumer for the suspension of trade. Alternatively, using autarky prices $p^a$ as the evaluation criteria, we obtain the Slutsky equivalent variation measure of the gains from trade:

$$\Delta I^{EV} = p^aC^t - p^aC^a.$$  

(2)

$\Delta I^{EV}$ is the change in income that would enable the representative consumer to attain the free trade consumption bundle at autarky prices. While the sign of (1) follows from optimizing behaviour, the sign of (2) follows from (1) and the assumption that consumer behaviour, in the aggregate, follows the weak axiom of revealed preference.

Since (1) and (2) require aggregate consumption data under both autarky and trade, which are usually not available, they are difficult to implement empirically. Furthermore, although (1) and (2) capture the magnitude of the gains from trade, they are silent regarding the underlying reallocation of resources that underpins these gains.

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8 Bernhofen and Brown (2005) shows that data on commodity autarky prices and trade flows provide an upper bound for the Slutsky equivalent variation measure (2) in a case where autarky commodity prices are observable.
2.2 A factor content formulation

We suggest a characterization of the welfare effects of trade that captures the distance between $C^a$ and $C^t$ by comparing the resources necessary to produce these consumption vectors. Assume the economy is able to produce the $n$ goods from $k$ primary factors of production. The $k$-vector of the economy's factor endowments is denoted by $L$. The economy’s domestic technology is given by an $n \times k$ matrix $A$, where an entry $a_{ij}$ denotes the number of units of factor $i$ necessary to produce one unit of good $j$.\(^9\) Full employment under autarky implies then that $L = AC^a$. The endowment vector necessary to produce $C^t$ with domestic production techniques is then given by $L_{\text{aug}} = AC^t$. The resource augmentation, denoted by $\Delta L = L_{\text{aug}} - L$, which would be required to produce the free trade consumption domestically and eliminate the need for international trade can then be written as:

\[
\Delta L = AC^t - AC^a
\]  

(3)

The advantage of (3) is that $\Delta L$ can be inferred from the economy's observed trade. Denoting the economy's $n$-vector of production under trade as $P^t$, the $n$-vector of net imports is then given by $T = C^t - P^t$. Applying the full employment condition ($AP^t = AC^a$), the resource augmentation is revealed by the economy's factor content of trade: $\Delta L = AC^t - AC^a = AT$.

Let us now split the economy's trading vector into its individual components, where $M$ denotes the vector of imports and $X$ the vector of exports. Accordingly, the domestic technology matrix can then be written as $A = (A^m, A^x)$, where $A^m$ is the matrix of input requirements of imports and $A^x$ is the matrix of input requirements of exports. Intuitively, our welfare characterization is based on a cost-benefit framework. Exports are the costs of international trade since they result in resource outflows that are captured by the factor content of exports, defined as $A^xX$. Imports

\(^9\) For simplicity, we assume fixed input coefficients, which implies that input coefficients do not depend on factor prices.
are the gross benefits from trade. Under the assumption that the import vector $\mathbf{M}$ could have been produced with domestic technologies, the gross benefits from trade are the counterfactual resources that would have been necessary to produce the imported goods domestically, which is the vector $\mathbf{A}^\text{mM}$. The resulting net benefit from trade is then simply $\mathbf{A}^\text{mM}-\mathbf{A}^\text{X}$. Trade can be thought of as augmenting the domestic endowment vector from $\mathbf{L}$ to $\mathbf{L}^\text{aug}=\mathbf{L}+\mathbf{A}^\text{mM}-\mathbf{A}^\text{X}$. Hence, (3) can be rewritten as:

$$\Delta \mathbf{L}=\mathbf{L}^\text{aug}-\mathbf{L}=\mathbf{A}^\text{mM}-\mathbf{A}^\text{X} \tag{4}$$

### 2.3 Ricardo's one factor model and the gains from trade

The factor content formulation of the gains from trade is most easily illustrated in the one factor Ricardian model. Figure 1 depicts the familiar textbook scenario in which the economy is able to produce two goods (cloth and wine) from a labour endowment $\mathbf{L}$ with unit-labour requirements given by $a_c$ and $a_w$. Prices are assumed to be such that the economy has a comparative advantage in cloth in which it also completely specializes. Preferences are such that the economy finds it optimal to export $X_c$ units of cloth for $M_w$ units of wine resulting in the consumption point $\mathbf{C}^t$, which yields a higher level of utility than autarky consumption $\mathbf{C}^a$. The income equivalent approach (measures (1) and (2)) captures the distance between autarky and free trade consumption by evaluating $\mathbf{C}^a$ and $\mathbf{C}^t$ at regime-specific goods prices. The resource augmentation approach exploits the fact that the economy’s trade vector $(X_c,M_w)$ contains information about the difference between the resources embodied in $\mathbf{C}^t$ and $\mathbf{C}^a$. Since there is only a single factor, (4) characterizes the gains from trade in physical labour: $\Delta \mathbf{L}=\mathbf{L}^\text{aug}-\mathbf{L}=a_wM_w-a_cX_c$. $\mathbf{L}^\text{aug}$ can be thought as a "labour augmentation equivalent to trade." In this view, trade relaxes the economy’s resource constraint such that the trade consumption point $\mathbf{C}^t$ could be produced with domestic technology and $\mathbf{L}^\text{aug}$. A virtue of this formulation is that the labour
content of trade is a sufficient statistic for the gains from trade and requires only data that are observed in the trading equilibrium.

Our measure has a historical precedent in David Ricardo’s famous passage which discusses the trade in cloth and wine between Portugal and England. This passage employs what Samuelson (1969) so vividly labelled “Ricardo’s four magic numbers” (where the numbers are given in italics):

England may be so circumstanced, that to produce the cloth may require the labour of 100 men if she attempted to make the wine, it might require the labour of 120 men for the same time. England would therefore find it her interest to import wine, and to purchase it by the exportation of cloth. To produce the wine in Portugal, might require only the labour of 80 men for one year, and to produce the cloth in the same country, might require the labour of 90 men for the same time, It would therefore be advantageous for her to export wine in exchange for cloth. Ricardo (1817, p. 82)

Following John Stuart Mill’s interpretation, trade theorists have interpreted Ricardo’s four numbers as unit labour coefficients: the amount of labour required in each country to produce one unit of cloth or wine. More recent appraisals of this interpretation suggest that it suffers from a serious shortcoming: it is inconsistent with Ricardo’s explication. At the outset, Ricardo introduces the first two numbers and then uses them to predict England’s pattern of trade without reference to the third and fourth numbers. If these were unit labour coefficients, the logic of the argument would require information on all four numbers before Ricardo could state a conclusion about the pattern of England’s (and Portugal’s) trade.

Drawing upon earlier work by Sraffa (1930), Ruffin (2002) and Maneschi (2004) suggest that Ricardo’s four numbers pertain to the amount of labour embodied in each country’s exports
and imports rather than unit labour coefficients. Bernhofen (2009) argues further that the labour content interpretation yields a pattern of trade prediction which restores coherence to this famous passage and is compatible with Ricardo’s labour theory of value.

Ricardo’s passage is compatible with Figure 1, where England exports $X_c$ units of cloth and imports $M_w$ units of wine. Since Ricardo’s comparative advantage formulation was embedded in his labour theory of value, he expressed the commodity exchange in labour units. Ricardo’s assertion that “the cloth may require the labour of 100 men” implies that $100 = a_c^E X_c$ and his assertion that “if she attempted to make the wine, it might require the labour of 120 men” implies that $120 = a_w^E M_w$. England’s gains from trade can then be expressed as $\Delta L^E = a_w^E M_w - a_c^E X_c = 120 - 100$, or, as Sraffa (1930, p. 54) put it “England gains the labour of 20 Englishmen.” Analogously, Portugal’s gains from trade can be written as $\Delta L^P = a_c^P M_c - a_w^P X_w = 90 - 80$ and “Portugal gains the labour of 10 Portuguese” Sraffa (1930, p. 54).

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10 In what follows, superscripts $E$ and $P$ pertain to England and Portugal.
11 If $T_c = T_w$, then Sraffa’s and Mill’s interpretations coincide.
2.4 Multiple factors

In our discussion of the Ricardian model we assumed positive gains from trade, which can be expressed in physical labour units. If there are additional factors, the welfare valuation of the factor augmentation (4) will generally require the employment of factor prices. We start out by defining the cases where the existence of the gains from trade can be established without requiring factor prices. Figure 2 illustrates the two-factor case where the economy's endowment vector $L$ partitions the endowment space into four quadrants: I, II, III and IV. If trade results in an augmentation of factors such that $L^{aug}$ falls either in quadrant I or III, the magnitude of the gains from trade can be expressed as in the Ricardian model without reference to factor prices. In Figure 2, $A^m M_1 - A^x X_1$ depicts the case where the economy gains in both factors and $L^{aug}$ falls in quadrant I. In this case, the relative gain of any factor $i$ can be expressed as a percentage increase of its endowment $L_i$. Figure 2 also includes the case $A^m M_2 - A^x X_2$. Here, $L^{aug}$ falls in quadrant III. Gains from trade are negative and the economy gives up more by exporting than it receives through its imports.\(^{12}\)

If the factor content of trade reveals that $L^{aug}$ falls either in quadrant II or IV, resource augmentation through trade will result in a factor trade-off. Figure 3 illustrates the case where the economy gains factor 2 at the expense of factor 1. To evaluate this factor trade-off in terms of social welfare, it is helpful to take the viewpoint of a social planner who is evaluating the net gain associated with $L^{aug}$. Recognizing that a competitive autarky equilibrium can be replicated by a constrained optimization problem in which the social planner faces the resource constraint $L$, the economy's autarky factor price vector $w^a$ constitutes the shadow prices at which she evaluates any changes in the economy's resource constraints. Since she will view trade as beneficial only if

\(^{12}\) Neoclassical trade theory predicts that $L_2^{aug}$ should never be observed in a world without government distortions. Since the factor content of trade can reveal negative growth in both factors, the gains from trade become an empirically refutable proposition.
\( w^a(A^mM) > w^a(A^xX) \), the net gain in social welfare is \( w^a(A^mM) - w^a(A^xX) \). We can now define a welfare measure which resembles the Slutsky equivalent variation measure in (2). Starting from the autarky equilibrium, we can consider the increase in factor income which would be equivalent to obtaining the augmented endowment point \( L^{\text{aug}} \) at the autarky factor prices \( w^a \). This factor content equivalent measure, denoted by \( \Delta L^{\text{EV}} \), is then:

\[
\Delta L^{\text{EV}} = w^a L^{\text{aug}} - w^a L = w^a(A^mM) - w^a(A^xX). \tag{5}
\]

Figure 3 provides an illustration of this measure. Drawing a line through \( L \) with the slope given by \( -(w_1^a/w_2^a) \), we obtain what can be termed an “autarky factor income line.” The intercept of the autarky factor income line with the horizontal axis gives the economy's autarky GDP \( (w^a L) \) in units of factor one. The factor content equivalent measure is then the distance between \( L^{\text{aug}} \) and \( L \), evaluated at autarky factor prices.

A shortcoming of the factor content equivalent measure is that autarky factor prices are usually not observable. Alternatively, we can evaluate the distance between \( L \) and \( L^{\text{aug}} \) using the economy's factor prices in the trading equilibrium. For this purpose, we introduce the concept of an “equivalent autarky equilibrium”:

**Definition:** An “equivalent autarky equilibrium” is an equilibrium that would arise if trade were suspended, but if the economy’s endowment vector were augmented to \( L^{\text{aug}} = L + A^mM - A^xX \).

Given a trading equilibrium where the economy is incompletely specialized, Deardorff and Staiger (1988) have shown that an equivalent autarky equilibrium exists such the economy's

\(^{13}\) An attractive feature of the shadow price interpretation associated with changes in the resource constraints is that social welfare gains can be expressed without knowledge of the consumption objectives of the society (see Dixit (1990), p.43).

\(^{14}\) Deardorff (1982) has shown that the gains from trade in its revealed preference formulation is a sufficient condition for \( \Delta L^{\text{EV}} \) to be positive. However, whereas Deardorff (1982) links the sign of (4) to a general Heckscher-Ohlin pattern of trade prediction, we argue that the magnitude of (4) captures the gains from trade.
new endowment vector $L^{\text{aug}}$ will produce the free trade consumption vector $C^t$ with domestic technologies and the same goods and factor prices $p^t$ and $w^t$ as under trade. In the equivalent autarky equilibrium, total factor income $w^t L^{\text{aug}}$ must then equal total aggregate expenditure $p^t C^t$.

Starting out from the trade-equivalent autarky equilibrium, we consider the change in the economy’s total factor income, evaluated at $w^t$, which would compensate the economy from eliminating its trade-equivalent factor augmentation back to $L$. We define this as the factor content compensating measure of the gains from trade and denote it by $\Delta L^{\text{CV}}$:

$$\Delta L^{\text{CV}} = w^t L^{\text{aug}} - w^t L = w^t (A^{mM}) - w^t (A^X).$$

(6)

An advantage of $\Delta L^{\text{CV}}$ relative to $\Delta L^{\text{EV}}$ is that it is not based on autarky prices. However, comparing the magnitudes of (5) and (6) will depend on how trade affects factor prices, which is complex unless one is willing to impose strong assumptions on consumer and production conditions which we will refrain from doing.16

2.5 Decomposing the gains from trade

In the Ricardian model, the gains from trade stem from productivity differences and the factor content measure provides a physical labour augmentation formulation of the gains from trade as illustrated in Figure 1. The Heckscher-Ohlin model abstracts from technological differences and the gains stem from countries exploiting their relative factor abundance. Two important questions arise. How can we disentangle whether trade is caused by differences in

15 Deardorff and Staiger (1988) develop the concept of an autarky equivalent equilibrium to show that the factor content of trade can be used to examine the effects of trade on factor prices. Deardorff (2000) provides a generalization and resolves some confusions that have arisen in the literature. More recently, Burstein and Vogel (2011) extend this framework to imperfect competition and heterogeneous firms. However, none of these papers link the factor content of trade to aggregate gains from trade.

16 In the special, but empirically unrealistic case where the free trade equilibrium is characterized by factor price equalisation, $\Delta L^{\text{CV}}$ will be equal to zero since the right-hand side of (6) reflects the balanced trade condition. This suggests that $\Delta L^{\text{C}}$ should be thought of as a lower estimate of the gains from trade.
factor productivity or in endowments? Is it possible to measure the relative importance of each cause? We suggest an approach to answering both questions.

Previously, we measured the gross benefits by from trade by applying the domestic technology matrix $A^m$ to obtain the counterfactual resources, denoted by $A^mM$, which would be necessary to produce the imported goods domestically. Alternatively, we can calculate the factor content of imports by using the technologies at the actual location of foreign production.\(^\text{17}\)

Denoting the matrix of foreign input requirements with $A^*$, $A^*M$ captures the actual inflows of resources embodied in imports. The gains from trade can then be decomposed as follows:\(^\text{18}\):

$$\Delta L^{CV} = w^a(A^mM) - w^a(A^*X) = w^aA^*M - w^aA^*X + w^a(A^*M - A^*M). \quad (7)$$

The expression (7) suggests a way to decompose $\Delta L^{CV}$ into an “actual” factor exchange component ($w^aA^*M - w^aAX$) and a technological difference component ($w^a(A^m-A^*)M$). The factor exchange component captures the actual factor content of imports, since it evaluates imports using the technologies actually used to produce them. However, since foreign factors differ in their productivities, the technological difference component captures the contribution of factor productivity differences in the overall gains from trade. Formally, we can consider the following definition concerning the decomposition of the gains from trade.

**Definition** of the decomposition of the gains from trade:

Assume that $w^aA^*M \geq w^aA^*X$ and $w^aA^mM \geq w^aA^*M$, then we define $\lambda = (w^aA^*M - w^aA^*X) / \Delta L^{EV}$ as the share of gains arising from factor exchange and $1 - \lambda = w^a(A^m-A^*)M / \Delta L^{EV}$ as the share arising from technological differences (0 < $\lambda$ ≤ 1).

\(^\text{17}\) Deardorff (1982) introduces the idea of calculating the factor content of trade at the actual location of production.

\(^\text{18}\) Without loss of generality, we illustrate the decomposition using the factor content equivalent measure.
Note that $\lambda$ is an aggregate measure which weighs unit factor requirements by import volumes and autarky factor prices. The data might reveal a value of $\lambda$ close to 1 despite significant country differences in input requirements in some sectors if the import volumes in these sectors are comparatively small. If $\lambda=1$, technological differences make no contributions to the overall gains from trade. A smaller value of $\lambda$ indicates a larger role for differences in technology. However, since $\lambda>0$, a boundary case where the gains stem entirely from differences in technology does not exist.

Consider the boundary case where the data reveal that $A^mM=A'M$. In this case the technological difference component vanishes. From an empirical perspective, this outcome would be indistinguishable from the case where home and foreign had identical technologies, i.e. $A^m=A'$. In this case the gains stem entirely from Heckscher-Ohlin and the factor augmentation will be characterized by a factor trade-off, as illustrated in Figure 3.

Figure 4 gives depicts the decomposition (7) graphically for the case where technological differences result in a factor augmentation where all components in $L_{aug}-L$ have a positive sign. Since foreign factor services embodied in imports are given by $A'M$, actual factor exchange results in an augmentation of the home endowment to $L+A'M-A'X$. However, this doesn't capture the entire gains for the domestic economy if foreign factors are more productive than domestic factors. The vector $A^mM-A'M$ captures this productivity adjustment that results from differences in amount of factors required by domestic and foreign technologies to produce $M$. In Figure 4, the technological differences are sufficiently large such that the domestic economy gains in both factors. In this scenario, which is similar to the one-factor Ricardian model, the gains can be expressed in physical factor terms in addition to $\Delta L^E$ and $\Delta L^C$. 
3. Empirical implementation

The opening up of Japan to international trade in 1859 after over two centuries of near autarky provides an unusual opportunity to apply the Ricardian factor content characterization of the gains from trade. Bernhofen and Brown (2004, (2005) describe this episode in detail. A central feature of the case of Japan is that during its early trading years of 1865-1876 it primarily imported goods with very close domestic substitutes. This allows us to calculate the counterfactual domestic input requirements that would have been necessary to produce foreign imports with domestic production techniques.

The implementation of our gains from trade measures in sections 2.2-2.4 requires data on trade flows, domestic input requirements and factor prices. The decomposition in section 2.5 requires additional data on foreign input requirements. We restrict our analysis to the years 1865, 1867-1876. Although Japan officially opened up to trade on July 4, 1859, the government of Japan was able to restrict the sale of its main exports (products of the sericulture industry) until western military intervention ended these efforts in 1864. Complete trade records for 1866 are missing because of a fire in the customs house of the main trading port, Yokohama. The last trading year chosen is well before significant imports of western technology starting in the 1880s altered the Japanese technology matrix that prevailed for the first period of open trade.

3.1 Data sources and variables

A data appendix available from the authors provides information on the historical sources used to construct the vectors of exports $X$ and imports $M$ and the technology matrices of Japan and of its trading partners. The abundant documentation allows us to define the trading vector at the level of individual products, or at a level of detail
comparable to the most disaggregated level for contemporary trade data. For example, ten per cent of Japan’s imports were an unfinished lighter cotton cloth known as gray shirtings. The sources note that almost all of the cloth was imported from Great Britain and the most common weight was 8.25 lbs. for a piece with a length of 40 yards and a width of 39 inches. The commentary provided on imports permits identification of the chief country supplying a particular product. With the well-documented exceptions of some woolens imported from France and Germany, Great Britain accounted for seventy or eighty per cent of the trade in imported manufactures. Imports of food and raw cotton were from China or Formosa. India provided indigo and the United States kerosene. The level of detail permits a close match between the elements of the technology matrices and the trade vector.

A review of the technologies for both Japan and the main source countries for its imports suggested that the A matrices should be defined over five factors of production that would capture two essential features of technologies of the last third of the nineteenth century: the presence of a division of labour by sex (in both the east and the west) and significant cross-national and cross-industry differences in the use of skilled labour. For that reason, the matrix uses three categories of labour measured in days per unit of output: skilled male, unskilled male, and female. The fourth factor is capital, which is the user cost of capital measured in terms of gold ryō with the purchasing power of 1854-
The final factor is land. To facilitate comparisons with Japanese sources, land is measured in terms of *tan*, which is equivalent to one-tenth of a hectare or one-quarter of an acre.

The compilation of the $A^x$ matrix included 23 different products; about 80 per cent of Japan’s exports were concentrated in just three of these: the products of its sericulture industry (raw silk and silkworm eggs) and green tea. The main source for the resource requirements for these exports is the exhaustive prefecture-by-prefecture survey of agricultural production conditions from the late 1880s, the Nōjji Chōsa (see Chō, Shōda and Ōhashi (1979)). Coal, copper, various maritime products, mushrooms, camphor and vegetable wax accounted for almost all of the rest. The construction of the $A^x$ matrix for these products took account of two features of the division of labour in production systems: the locus of most production in vertically disintegrated and non-specialized units, which were primarily rural households linked together by local markets, and the extensive use of female labour for particular tasks on the farm and a limited number of skilled craftsmen at key points in production processes. Japanese and western sources provide ample documentation of all stages of production processes, so that the resource requirements for key intermediate goods such as mulberry leaves, fertilizer, coal, charcoal and lumber can be readily included in the calculation of the net resource requirements. For example, one pound of raw silk, Japan’s most important export, required about 15 days of male labour and 4 days of female labour. Of this amount, most of the male labour was required for raising mulberry leaves (one pound of

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21 The gold ryō was the gold-based currency of Japan until it was replaced with the yen in 1871 at one-to-one. Yen and ryō values for years other than 1854-1857 were deflated using the index of non-tradable goods found in Shinbo (1978, Table 5-10).
raw silk requires 360 pounds of leaves). Three-quarters of the female labour was for reeling, and the remainder was for raising the other intermediate products of silkworm eggs and cocoons. Since the sericulture industry resulted in a number of joint products that could essentially be treated as waste, input requirements were adjusted to assume that all output was of a high enough quality to be exported.

For the $A^x$ matrix, workers on the farm were included among unskilled workers. The category of skilled male workers includes production workers with specialized skills (such as smelters or tea sorters) and owner-operators of specialized small firms such as fishermen. Capital costs took account of the relatively high rates of depreciation of wooden tools and equipment and the high rates of interest that prevailed in Japan during the test period.\(^{22}\) Finally, all measured land is assumed to be useable as cropland, or its equivalent in Japan, dryfield land.\(^{23}\)

The construction of the $A^m$ matrix followed the same procedure as was used for the $A^x$ matrix. Essentially, the $A^m$ matrix provides the Japanese technologies that could be used to produce Japan’s imported goods. The Nōji Chōsa provided source information for Japanese technologies for producing imported agricultural goods such as indigo, rice, soybeans and unrefined sugar. Historical studies of Japanese firms provide information on the refining stages of products such as indigo and sugar. Several studies, most notably Tanimoto (1998), provide detail on the stages of production and technologies used in the

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\(^{22}\) See Saitō and Settsu (2006) for a review of the available evidence, which places the range in 12 to 15 percent.

\(^{23}\) Japanese land consisted of dryfields, which were used for crops such as cotton, soybeans and indigo, and paddy land, which was used for rice.
cotton textile industry.24 The detailed reports of the American geologist Benjamin Smith Lyman (see Lyman (1879)) provide comprehensive accounts of Japanese technologies for drilling and refining petroleum, mining, smelting and metallurgy.

The one product that deserves particular mention is woolen and worsted cloth, which accounted for 21 per cent of Japan’s imports by value. Japan’s topography does not lend itself to the widespread grazing of sheep, so that prior to the 1880s, Japan did not produce any woolens. Historians such as Tamura (2004) have established that imported woolens by and large substituted for various kinds of silk in Japanese dress.25 A key import during the 1860s, camlets (a moderate-weight worsted cloth), was used for belts and haori (outer jackets). Mousseline de laine and other lightweight worsted or mixed cloths that came to dominate imports during the 1870s substituted for domestic silk cloths such as chirimen in the sewing of kimonos. To account for the resources required by woolen imports, woolen and worsted cloths were grouped into three categories by weight; the resources required to produce the same square yardage of similar silk cloths were then calculated. The main sources for the requirements for silk cloths include Bavier (1874), Porter and National Association of Manufacturers (U.S.) (1898) and Ichikawa (1996). The three cloths were chirimen, habutai and hakata-obi.

The construction of the $A^*$ matrix took account of the production location of the largest supplier to the Japanese market.26 This approach took full account of the heterogeneity of production conditions across supplier countries and within individual

24 The $A^m$ matrix was constructed to accommodate different cloth weights. It assumed that all imported finished cloth was dyed using indigo dye.
25 The major exceptions were the heavier woollen cloths that were used for military uniforms, the uniforms of some government employees and the western dress that was sometimes worn by a small elite minority.
26 Typically, the largest supplier amounted to seventy or eighty percent of the Japanese market.
industries. For example, depending upon the cloth, the British cotton industry used either cotton from India or from the United States. The woolen industries of Europe produced cloths that varied according to the use of worsted, woolen or cotton yarn; the use of power instead of hand looms; the source of wool (domestic or imported from the southern hemisphere); and the amount of finishing. All of these differences affected the amount and the distribution of resources embodied in imports into Japan.

The matrix of input requirements for imports \( A^* \) includes information on five different groupings of cotton cloth and eleven groupings of woolen cloths. In addition, it includes input requirements for fourteen other products. As with the \( A^m \) matrix, the resource requirements for imports were assigned to the three categories of labour, capital and land. Capital was measured in yen at the appropriate prevailing exchange rate and then converted to ryō of the mid-1850s following the procedure outlined above. With the exception of land that was used to graze sheep, all land was treated as equivalent to Japanese dryfields. Relative rents on land used to raise sheep were used to convert that land to a dryfield equivalent.\(^{27}\) Input requirements could be ascertained for over 81 per cent of Japan’s imports by value. The largest category lacking information was for imported ships and cannon, which were both important imports in 1865-1868.

Finally, the vectors of factor prices \( w^a \) and \( w^t \) must meet two criteria. First, they must take full account of potential differences in the two most important economic regions of Japan during autarky and open trade: the Kinai in the west (centered on Kyoto and Osaka) and the Kantō, centered on Edo (Tokyo) in the east. The estimates of wages

\(^{27}\) The data appendix provides a complete discussion of the procedure. The adjustment used the ratio of the rent on pasture land in the respective sheep growing country (such as Australia) to the rent on cropland in England to make the conversion to a dryfield equivalent.
for unskilled male workers and females for both the autarky (ca. 1855) and open trade periods (ca. 1878) were derived from Saitō (1998). Several other local industry studies provided supplementary data on wages for skilled workers during both periods.28

The second criterion is to take account of the fact that land varied in quality and use and by location. A tan of a dryfield of low quality would rent for a fraction of the rent of highest-quality paddy land. Detailed land price and rent evidence that includes information on both characteristics is available for several locations in the west and two locations in the east, which allowed for the estimation of hedonic regressions. The average predicted rent from these regressions for good quality dryfields in the west was up to 1.82 ryō per tan; it reflects the productivity of land in the region that supplied most of Japan’s raw cotton. Data on the average productivity of land for Japan as a whole relative to the sample villages used in the hedonic regressions were used to convert the predicted rents in the Kinai to an average rent of 1.04 ryō for all of Japan.29 Data on land values for the open trade period becomes plentiful during the 1870s. Property transactions recorded in the *Tokyo Journal of Economics (Tokyo Keizai zasshi)* provide coverage for much of Japan for paddy land. These rents are adjusted downwards by about one-half to provide an estimate of rents for dry fields.30 Capital was the numéraire for the autarky period (priced at one ryō). For the open trade period, the price of capital was inflated to reflect the diminished purchasing power of the ryō by the mid-1870s. The

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28 Autarky day wages were 0.053, 0.031 and 0.019 ryō ca. 1855. Wages ca. 1878 were about 0.15, 0.12 and 0.09 yen.

29 Le Gendre (1878, Appendix Table) provides the data on productivity per tan for all of Japan’s prefectures ca. 1874.

30 The rents are 1.04 ryō per tan (one-quarter acre) in the mid-1850s and 4 yen per tan in 1878.
price index for non-tradable goods published in Shinbo (1978, Table 5-10) was used to arrive at a price of capital that was 4.1 yen ca. 1878.

3.2 Assessing the augmentation of factor endowments resulting from trade

Table 1 provides information on Japan’s factor augmentation ($L^{aug}-L$) from equation (4) and its individual components for each sample year. Factor flows of the three types of labour are measured in millions of days; capital is given in thousands of ryō; and land in thousands of tan. Panel A documents the resource outflows embodied in Japan’s exports, $A^X$. Panel B gives the counterfactual resources necessary to produce Japan’s imports domestically, $A^M$. Panel C gives $A^M-A^X$, the factor augmentation necessary to produce Japan’s free trade consumption vector domestically. A striking feature of Panel C is that the factor content reveals a factor augmentation in each factor in each sample year. In terms of Figure 2, Japan’s factor content of trade reveals no factor trade-off so that its augmented endowment vector $L^{aug}$ lies in quadrant I in each sample year. Since the economy is “gaining in all factors,” Panel C provides causal evidence of the existence of the gains from trade. A striking feature of the gains in the labour categories, which are easily comparable because all are measured in terms of days of work, is the large augmentation of female labour relative to skilled and unskilled male labour. Depending on the sample year, the gain in female labour services is between two to three times the total gain in male labour. This gain in female labour can be explained by Japan’s intense use of female labour in import-competing sectors such as yarn and cloth.

Another interesting feature of Panel C is the time series pattern of augmentation in the individual factors. While the augmentation of skilled labour remained relatively flat, the augmentation of the other factors increased over the sample period. Between the mid-1860s and the mid-1870s, the augmentation of unskilled male workers and land roughly doubled, and the augmentation of female workers and capital almost tripled. This reveals increased specialization and increased gains from trade; it may reflect the adaptation of Japanese producers to world
market conditions and improved matches between the and the goods on offer by western merchants and the tastes of Japanese consumers.

An implicit assumption of the theory is that the economy operates under balanced trade. In a trade deficit year, the economy can be thought of as borrowing foreign factor services and the factor content will overstate the gains from resource reallocations. In a trade surplus year, the economy can be thought of as lending domestic factor services and the factor content will understate the gains from trade. The simplest procedure to correct trade balances is to assume that Japanese preferences are homothetic so that imports are scaled up in trade surplus years and scaled down in trade surplus years so that the adjusted imports satisfy the balanced trade condition. Panel D in Table 1 gives the factor augmentation adjusted for trade imbalances. Since 1865 and 1868 saw considerable trade surpluses, the adjustments to the factor augmentations are larger in these years. Since 1876 was a year of a smaller trade surplus, the adjustments are less significant. Since the remaining were trade deficit years, the trade adjusted augmentations were all smaller in these years. Overall, the basic pattern seen in Panel C remains.

An attractive feature of our characterization is that the gain in factor i can be expressed as a percentage increase in the economy’s endowment \( L_i \) of that factor.\(^{31}\) Censuses conducted in the mid-1870s suggest that there were about 10.5 million male workers and about 8.5 female workers. Consistent with the historical literature, children under 15 were not included in the labour force.\(^{32}\) The census results also suggest that Japan was endowed with about 48 million tan

\(^{31}\) It is important to remind ourselves that this gain to the physical factor endowment is an aggregate gain to the entire economy and has nothing to do with changes in the purchasing power of individual factors of production. We know from Stolper-Samuelson that some factors will gain and others will lose in terms of purchasing power, i.e. relative changes in factor versus goods prices.

\(^{32}\) Van Buren (1880, pp. 37 and 45) provides these estimates. Contemporary Japanese sources do not distinguish between skilled and unskilled male labor. Consistent with historical sources, we assume a labor year of about 300 days of labor. The sources are insufficiently detailed to provide a reliable estimate of the capital stock.
of cultivated land.\textsuperscript{33} For the years 1869 and 1870, when poor harvests led to large imports of rice and beans, the augmentation of cultivated land reached almost 5 per cent of Japan’s endowment. For the post-crisis years of 1871-1876, the average was about 2.7 per cent (see the final column of panels C and D). Imports of male labour were about 3 per cent of the endowment. During the 1871-1876 period, factor trade accounted for the equivalent of a ten per cent increase in female labour.

Information on factor prices from the autarky period and the end of our test period allows us to assess how much the factor flows in Table 1 were translated into welfare gains under two different counterfactual assumptions. Consider first the results for the factor content equivalent measure $\Delta L^\text{EV}$ developed in section 2.4 (equation (5)). This measure captures the increase in factor income that would have made free trade consumption affordable in the 1850s by valuing the net factor imports at the autarky factor prices prevailing in the mid-1850s.\textsuperscript{34} The values in Panel A of Table 2 are expressed in current ryō, in ryō per capita, and as a share of per capita GDP. The per capita GDP used here is based upon a study of a prosperous feudal territory of Tokugawa Japan from 1842.\textsuperscript{35} The per capita values of the equivalent variation have been adjusted to reflect the potential growth of the economy between the autarky period (1855) and the sample years (1865 through 1876).\textsuperscript{36} The estimated gains range from seven to 14 per cent of

\textsuperscript{33} One tan is about 0.25 acres.  
\textsuperscript{34} This is the factor income equivalent to the Slutsky compensation estimate given in Bernhofen and Brown (2005).  
\textsuperscript{35} Nishikawa (1987) estimates that the feudal territory or han of Chōshū had a per capita income of about 2.53 ryō in the early 1840s. With a growth rate of 0.4 percent, that would be about 2.67 by 1855. This han had a higher share of its population (about 15 percent) in the secondary and tertiary sectors than most of Japan. Household income in these sectors was about 2.5 times incomes in agriculture. If we assume a more realistic share of 10 percent outside of agriculture, the per capita income would be about 2.52. This estimate is used for the calculations of the equivalent variation measure expressed as a share of GDP.  
\textsuperscript{36} Growth of the economy from 1855 to the trade year would increased the production potential of the economy. The equivalent variation measure has been deflated by an estimated growth rate of per capita GDP of 0.4%, which Nishikawa (1987, p. 327) suggests characterized growth during the earlier part of the century.
GDP, with an average of 11.7 per cent for the entire test period. This is only slightly higher than the roughly comparable consumption equivalent variation "forecast” estimate of 8.9 per cent calculated using information on trade and autarky prices for a slightly shorter period and reported in Bernhofen and Brown (2005, Table 4). The results suggest that the gains from trade increased by one-third to one-half from mid-1860s to the mid-1870s.

Panel B of Table 2 presents the calculations of the compensating variation measure of factor gains $\Delta L^{CV}$, which gives the change in the economy’s total factor income necessary to fully compensate for the elimination of the factor augmentation ($L^{aug} - L$) brought about by trade. Here, the change in factor income is evaluated at free trade factor prices ($w^f$). Panel B gives $\Delta L^{CV}$ in millions of yen, in per capita terms, and as a share of the estimate of GDP per capita over the years 1878-1882 provided by Okawa (1957, Table 1). Since GDP per capita must have grown over the test period, the final row of Table 2 includes the $\Delta L^{CV}$ under the assumption that the growth rate in GDP per capita was 0.4% over the period 1865-1876. Both sets of estimates suggest a similar conclusion. The mean gains from trade averaged six to seven per cent over the early period of open trade. The compensating variation estimates suggest that the gains from trade almost doubled from the mid-1860s to the mid-1870s.

We have noted in section 2.5 that the factor trade approach to the gains from trade allows for a decomposition of the gains into two sources: factor exchange and differences in technology. Table 3 contains the results of such a decomposition; it draws on a technology matrix $A^*$ that measures the factor requirements of Japan’s imports at the source of production. Panel A gives the results for $\Delta L^{EV}$ and Panel B gives the results for $\Delta L^{CV}$. The first two rows in each panel give the factor valuations of factor exports $A^X$ and imports $A^M$. Since $A^M$ can be thought as the “actual” inflows of foreign resources, $A^M - A^X$ (found in the third row of each panel) can be

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37 The earlier paper did not make adjustments for trade deficits or surpluses.
viewed as the exchange of factors that takes place with trade. It is positive in all years and peaks in 1870.

Since the actual factor exchange is positive for both factor valuations in both years, we can apply the gains from trade decomposition from section 2.5. Panel A gives the values of $\lambda_{EV} = \frac{(w^A M - w^A X)}{\Delta L_{EV}}$ and $1 - \lambda_{EV} = \frac{w^A (A^m - A^*) M}{\Delta L_{EV}}$; Panel B reports $\lambda_{CV} = \frac{(w^A M - w^A X)}{\Delta L_{CV}}$ and $1 - \lambda_{CV} = \frac{w^A (A^m - A^*) M}{\Delta L_{CV}}$. Despite using differing vectors of factor prices, both measures suggest similar conclusions. Technological differences accounted for from three-quarters to over ninety per cent of Japan’s gains from trade during the early trading period. The choice of factor valuation does not affect the time series as well. The role of factor exchange peaks in both series during 1869 and 1870, when Japan is able to draw on China for large imports of rice and beans. Both panels suggest a modest increase in the importance of the technological difference component in the overall gains from trade.

4. Conclusion

International trade can be viewed as a transformation of exports into imports. To be welfare improving, the benefits from imports must exceed the costs of exports. Generalizing Ricardo’s (1817) labour value formulation of comparative advantage to multiple factors and goods, this paper proposes a cost-benefit comparison in terms of the resources embodied in trade. An advantage of this cost-benefit formulation is that the gains from trade become an empirically testable hypothesis rather than a theoretical assumption. Furthermore, this approach allows for an examination of the underlying sources of the gains from trade. We also show that the factor content can be used as an analytical tool for the construction of factor content duals of the well-known equivalent and compensating variations measures of the gains from trade.

We employ our Ricardian factor content characterization of the gains from trade to 19th century Japan, where we are in an unusual position to observe a market-based economy both
under autarky and trade under the *ceteris paribus* assumption. We find evidence of positive gains from trade in all sample years; an augmentation of all factors provides direct evidence for gains from trade. By the mid-1870s, the augmentation in factor endowment equivalents could be up to ten per cent of the supply of female labour. Two alternative approaches to valuing factors of production help to establish the robustness of the empirical results; Japan’s comparative advantage gains from trade grew from one-third to almost 100 per cent over its first decade and one-half of recorded open trade. Decomposing the aggregate gains into factor exchange and technological difference components, we identify a large role for technological differences between Japan and its trading partners.

Although we applied our gains from trade measures to the case of Japan, the empirical domain of the factor content approach goes beyond this historic case. Our findings that factor valuations at autarky and free trade prices provide similar results should be a stimulus for future applications.
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Figure 1: Labour augmentation equivalent to trade
Figure 2: Evaluating the welfare effects of trade without factor prices
Figure 3: Factor content equivalent measure of the gains from trade

\[
\text{slope} = \frac{-w_1^a}{w_2^a}
\]
Figure 4: Decomposing the comparative advantage gains from trade.
Table 1: Factor flows between Japan and its trading partners

<table>
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<tr>
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<th>1867</th>
<th>1868</th>
<th>1869</th>
<th>1870</th>
<th>1871</th>
<th>1872</th>
<th>1873</th>
<th>1874</th>
<th>1875</th>
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<td>1438</td>
<td>803</td>
<td>1201</td>
<td>2197</td>
<td>1922</td>
<td>1761</td>
<td>2284</td>
<td>2170</td>
<td>3035</td>
<td>2344</td>
</tr>
<tr>
<td>Land (thousands of ( \text{tan} ))</td>
<td>591</td>
<td>1124</td>
<td>443</td>
<td>1237</td>
<td>2571</td>
<td>2019</td>
<td>1451</td>
<td>1698</td>
<td>1415</td>
<td>1954</td>
<td>1258</td>
</tr>
<tr>
<td>Panel D: Net Imports of Factors: ( \mathbf{A}^m \mathbf{M} - \mathbf{A}^x \mathbf{X} ) corrected for trade imbalances</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male skilled (millions of days)</td>
<td>37</td>
<td>15</td>
<td>23</td>
<td>13</td>
<td>18</td>
<td>15</td>
<td>14</td>
<td>19</td>
<td>16</td>
<td>22</td>
<td>35</td>
</tr>
<tr>
<td>Male unskilled (millions of days)</td>
<td>52</td>
<td>39</td>
<td>47</td>
<td>43</td>
<td>96</td>
<td>74</td>
<td>61</td>
<td>68</td>
<td>62</td>
<td>86</td>
<td>109</td>
</tr>
<tr>
<td>Female (millions of days)</td>
<td>148</td>
<td>115</td>
<td>182</td>
<td>109</td>
<td>196</td>
<td>218</td>
<td>235</td>
<td>241</td>
<td>282</td>
<td>277</td>
<td>435</td>
</tr>
<tr>
<td>Capital (thousands of ( \text{ryō} ))</td>
<td>941</td>
<td>906</td>
<td>1207</td>
<td>938</td>
<td>1923</td>
<td>1480</td>
<td>1211</td>
<td>1557</td>
<td>1489</td>
<td>2152</td>
<td>2989</td>
</tr>
<tr>
<td>Land (thousands of ( \text{tan} ))</td>
<td>894</td>
<td>701</td>
<td>727</td>
<td>981</td>
<td>2273</td>
<td>1614</td>
<td>1052</td>
<td>1158</td>
<td>957</td>
<td>1360</td>
<td>1685</td>
</tr>
</tbody>
</table>
Source: For the procedure used to calculate the estimated factor flows, please see the text.

Notes: Information on the Japanese endowments of male and female labor and land are from the censuses of 1875 reported in {Van Buren, 1880 #28, pp. 37 and 45}. The net imports as a share of the endowment is for the average for each factor from 1871 through 1875.
Table 2: Estimates of the equivalent and compensating variation measures of the gains from factor trade

<table>
<thead>
<tr>
<th></th>
<th>1865</th>
<th>1867</th>
<th>1868</th>
<th>1869</th>
<th>1870</th>
<th>1871</th>
<th>1872</th>
<th>1873</th>
<th>1874</th>
<th>1875</th>
<th>1876</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Equivalent variation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta L^{EV}$ (in millions of ryō)</td>
<td>8.25</td>
<td>5.79</td>
<td>8.09</td>
<td>6.05</td>
<td>11.91</td>
<td>10.40</td>
<td>9.41</td>
<td>10.48</td>
<td>10.61</td>
<td>12.63</td>
<td>18.25</td>
</tr>
<tr>
<td>$\Delta L^{EV}$ per capita adjusted†</td>
<td>0.24</td>
<td>0.17</td>
<td>0.23</td>
<td>0.17</td>
<td>0.34</td>
<td>0.30</td>
<td>0.27</td>
<td>0.30</td>
<td>0.30</td>
<td>0.36</td>
<td>0.51</td>
</tr>
<tr>
<td>As share of GDP</td>
<td>0.10</td>
<td>0.07</td>
<td>0.09</td>
<td>0.07</td>
<td>0.14</td>
<td>0.12</td>
<td>0.11</td>
<td>0.12</td>
<td>0.12</td>
<td>0.14</td>
<td>0.20</td>
</tr>
<tr>
<td><strong>Panel B: Compensating variation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta L^{CV}$ (in millions of yen)</td>
<td>32.61</td>
<td>23.75</td>
<td>33.38</td>
<td>24.77</td>
<td>48.94</td>
<td>43.45</td>
<td>39.85</td>
<td>43.90</td>
<td>45.24</td>
<td>52.81</td>
<td>76.67</td>
</tr>
<tr>
<td>$\Delta L^{CV}$ per capita</td>
<td>0.930</td>
<td>0.677</td>
<td>0.952</td>
<td>0.706</td>
<td>1.396</td>
<td>1.239</td>
<td>1.136</td>
<td>1.252</td>
<td>1.290</td>
<td>1.506</td>
<td>2.186</td>
</tr>
<tr>
<td>GDP per capita 1878-1882</td>
<td>19.02</td>
<td>19.02</td>
<td>19.02</td>
<td>19.02</td>
<td>19.02</td>
<td>19.02</td>
<td>19.02</td>
<td>19.02</td>
<td>19.02</td>
<td>19.02</td>
<td>19.02</td>
</tr>
<tr>
<td>As share of GDP</td>
<td>0.05</td>
<td>0.04</td>
<td>0.05</td>
<td>0.04</td>
<td>0.07</td>
<td>0.07</td>
<td>0.06</td>
<td>0.07</td>
<td>0.07</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>GDP per capita adjusted‡</td>
<td>17.91</td>
<td>18.06</td>
<td>18.13</td>
<td>18.20</td>
<td>18.28</td>
<td>18.35</td>
<td>18.42</td>
<td>18.50</td>
<td>18.57</td>
<td>18.64</td>
<td>18.72</td>
</tr>
<tr>
<td>As share of GDP</td>
<td>0.05</td>
<td>0.04</td>
<td>0.05</td>
<td>0.04</td>
<td>0.08</td>
<td>0.07</td>
<td>0.06</td>
<td>0.07</td>
<td>0.07</td>
<td>0.08</td>
<td>0.12</td>
</tr>
</tbody>
</table>

†Adjusted for growth in production possibilities from 1855 to the relevant year at a rate of 0.4 percent per year.
‡Adjusted for growth in real GDP per capita to 1880 from the relevant year at a rate of 0.4 percent per year.

Source: $\Delta L^{EV}$: the inner product of the net imports of factors from Panel D of Table 1 and the vector of autarky factor prices. $\Delta L^{CV}$: the inner product of the net imports of factors from Panel D of Table 1 and the vector of open trade factor prices.

Notes: The ryō is the currency used in Japan during autarky. The yen was introduced in 1871 to replace the (paper) ryō at a ratio of one to one.
Table 3: Decomposing the contribution of factor exchange and productivity differences to the Gains from Trade

<table>
<thead>
<tr>
<th></th>
<th>1865</th>
<th>1867</th>
<th>1868</th>
<th>1869</th>
<th>1870</th>
<th>1871</th>
<th>1872</th>
<th>1873</th>
<th>1874</th>
<th>1875</th>
<th>1876</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A: Equivalent variation measure†</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$w^aA*M$</td>
<td>3.92</td>
<td>2.52</td>
<td>3.41</td>
<td>3.34</td>
<td>4.90</td>
<td>4.31</td>
<td>4.05</td>
<td>4.07</td>
<td>3.74</td>
<td>5.05</td>
<td>6.41</td>
</tr>
<tr>
<td>$w^aAX$</td>
<td>2.23</td>
<td>1.95</td>
<td>1.57</td>
<td>1.83</td>
<td>2.11</td>
<td>3.56</td>
<td>3.13</td>
<td>3.28</td>
<td>3.33</td>
<td>3.56</td>
<td>4.81</td>
</tr>
<tr>
<td>$w^aA*M-w^aAX$</td>
<td>1.69</td>
<td>0.57</td>
<td>1.84</td>
<td>1.51</td>
<td>2.79</td>
<td>0.75</td>
<td>0.92</td>
<td>0.78</td>
<td>0.41</td>
<td>1.49</td>
<td>1.60</td>
</tr>
<tr>
<td>$\lambda^{EV}$</td>
<td>0.187</td>
<td>0.098</td>
<td>0.203</td>
<td>0.251</td>
<td>0.234</td>
<td>0.072</td>
<td>0.097</td>
<td>0.075</td>
<td>0.038</td>
<td>0.118</td>
<td>0.088</td>
</tr>
<tr>
<td>$1-\lambda^{EV}$</td>
<td>0.813</td>
<td>0.902</td>
<td>0.797</td>
<td>0.749</td>
<td>0.766</td>
<td>0.928</td>
<td>0.903</td>
<td>0.925</td>
<td>0.962</td>
<td>0.882</td>
<td>0.912</td>
</tr>
</tbody>
</table>

Panel B: Compensating variation measure‡

<table>
<thead>
<tr>
<th></th>
<th>1865</th>
<th>1867</th>
<th>1868</th>
<th>1869</th>
<th>1870</th>
<th>1871</th>
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<th>1873</th>
<th>1874</th>
<th>1875</th>
<th>1876</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w^tAX$</td>
<td>8.68</td>
<td>7.46</td>
<td>6.10</td>
<td>7.08</td>
<td>8.12</td>
<td>13.74</td>
<td>12.04</td>
<td>12.67</td>
<td>12.80</td>
<td>13.69</td>
<td>18.59</td>
</tr>
<tr>
<td>$w^tA*M-w^tAX$</td>
<td>6.85</td>
<td>2.52</td>
<td>7.37</td>
<td>6.17</td>
<td>11.37</td>
<td>3.43</td>
<td>4.06</td>
<td>3.52</td>
<td>2.14</td>
<td>6.45</td>
<td>6.99</td>
</tr>
<tr>
<td>$w^t(AM-A*M)$</td>
<td>28.80</td>
<td>21.24</td>
<td>29.70</td>
<td>18.60</td>
<td>37.57</td>
<td>40.02</td>
<td>35.79</td>
<td>40.38</td>
<td>43.10</td>
<td>46.36</td>
<td>69.68</td>
</tr>
<tr>
<td>$\lambda^{CV}$</td>
<td>0.192</td>
<td>0.106</td>
<td>0.199</td>
<td>0.249</td>
<td>0.232</td>
<td>0.079</td>
<td>0.102</td>
<td>0.080</td>
<td>0.047</td>
<td>0.122</td>
<td>0.091</td>
</tr>
<tr>
<td>$1-\lambda^{CV}$</td>
<td>0.808</td>
<td>0.894</td>
<td>0.801</td>
<td>0.751</td>
<td>0.768</td>
<td>0.921</td>
<td>0.898</td>
<td>0.920</td>
<td>0.953</td>
<td>0.878</td>
<td>0.909</td>
</tr>
</tbody>
</table>

†Inner products are in millions of ryō.
‡Inner products are in millions of yen.

Notes: For a discussion of the calculations underlying these estimates, please see the text.