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Testing the general validity of the Heckscher-Ohlin theorem: the natural experiment of Japan

By
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Abstract

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Outline:

Non-technical summary

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1. Introduction

The Heckscher-Ohlin theorem is one of the central general equilibrium propositions in economics.[1] It predicts that the direction of trade is explained by differences in countries' relative factor scarcity. In Bertil Ohlin's (Ohlin (1933)) original formulation, relative factor scarcity is measured by countries' autarky factor prices. However, since autarky factor prices are rarely observed, empirical investigations of the Heckscher-Ohlin theorem have focused on the Leontief, or quantity formulation of Heckscher-Ohlin, as developed by Vanek (1968). This approach, known as the Heckscher-Ohlin-Vanek (HOV) model, has dominated the empirical Heckscher-Ohlin literature for the last three decades.[2] A shortcoming of the HOV formulation is that it is based on an integrated trading equilibrium characterized by the restrictive assumptions that all economies have identical technologies, identical factor prices and identical homothetic preferences.

This paper provides the first test of the general validity of the Heckscher-Ohlin theorem in its Ohlin, or price formulation. This formulation goes back to the seminal work by Deardorff (1982), who has shown that a country's autarky factor price vector imposes an empirically refutable restriction on the economy's factor content of trade. Specifically, it predicts that a country will, on average, export those goods that make relatively intensive use of its relatively abundant factor. An attractive feature of this formulation is that it does not require the

[1] We acknowledge the generous support of the National Science Foundation Grant SES-0452991 and Leverhulme Trust Grant F/00 114/AM. Shoji Masahiro, Matsuura Miki and Nakamura Kana provided excellent research assistance. Earlier versions of this paper were presented at the 2009 NBER Summer Institute, Hitotsubashi University, University of Lausanne, Essex University, Warwick University, University of Tokyo, University of Nottingham-Malaysia and Nanyang Technological University. We benefitted from comments by Marius Bruelhart, Don Davis, Gene Grossman, Kozo Kyoto, Tanimoto Masayuki, Ayako Obashi, Peter Neary, Mathias Thoeng, David Weinstein, John Whalley and Sugita Yoichi. We are particularly indebted to Alan Deardorff's extensive comments on a previous version of this paper.

[2] The most prominent contributions are Leamer (1980), Maskus (1985) , Bowen, Leamer and Sveikauskas (1987), Trefler (1993, 1995) and Davis and Weinstein (2001).

assumption of symmetric preferences and technologies across countries. The intuition for the greater generality of this result is that autarky factor prices embody more information about factor scarcity than factor endowments. Measures of factor endowments only provide information about relative factor supplies; equilibrium factor prices embody information about both factor supply and demand.[3] For example, consider a two-country, two-factor world where country A has a higher land-labour ratio than country B. If consumers in A have stronger preferences for land-intensive goods relative to consumers in B, country A could have a higher relative autarky price of land than country B. Since the preference bias for land-intensive goods outweighs the factor supply difference, country A will be relatively scarce in land in the Ohlin formulation and predicted to be a net importer of land-intensive goods. While the price formulation of Heckscher-Ohlin allows for this possibility, the quantity approach rules out such a scenario since it identifies trading patterns solely on differences in relative factor supplies.

A test of Heckscher-Ohlin with a formulation that measures factor scarcity as originally envisioned by Ohlin breaks new ground in a long and prominent literature.[4] The challenge of testing this formulation is that it requires compatible data of a market economy under both autarky and free trade. Bernhofen and Brown (2004, 2005) identified Japan's rapid integration into the international economy in the mid-19th century after over two centuries of nearly complete economic isolation as a natural experiment compatible with the autarky-free trade paradigm of neoclassical trade theory. They evaluated Japan's trade flows during the early open trade period with commodity prices from the last years of autarky and showed that Japan's commodity trading pattern behaved in accordance with the law of comparative advantage and provided upper bound estimates of the gains from trade.

[3] Hayek (1945) articulates the fundamental insight that prices embody all relevant information about relative scarcities in an economy.
[4] See Feenstra (2004, chapters 2 and 3) for an excellent survey of the literature.

For several reasons, the natural experiment of Japan is also well suited for a test of the autarky price formulation of Heckscher-Ohlin. First, as emphasized by Neary and Schweinberger (1986), the existence of positive gains from trade is a critical condition for deriving this prediction. In their study of Japan, Bernhofen and Brown (2005) find evidence of gains from trade using a revealed preference formulation so that the case of Japan appears to fulfil this critical assumption. Second, the most general formulation of the theorem requires that a country's factor content of trade is measured with the techniques used at the location of production. Our formulation allows for technological differences without imposing parametric restrictions on the nature of those differences.[5] Our measure of the factor content of trade is constructed from detailed historical data—much of it at the task level—on the direct and indirect input requirements of Japan's tradable goods. In contrast, measures of the factor content of trade from modern day economies are constructed from industry level input-output matrices in which thousands of products are grouped into broad industry aggregates. The detail available on technologies allows for a closer assignment of factor usage to the quantity of each traded commodity. It also permits ready inclusion of any significant trade in intermediate goods.

Our test combines factor price data from Japan's late autarky period with commodity trade data and home and foreign technology matrices from the early free trade period. The construction of the technology matrices draws upon many historical sources, including a major Japanese survey of agricultural techniques and a rich set of comparative cost studies from the last third of the nineteenth century. The study of the production conditions during this period suggests that a five factor classification is appropriate. The factors include skilled male labour,

[5] A non-parametric restriction on the nature of technological differences is spelled out in the theory section of the paper.

unskilled male labour, female labour, capital and land. The autarky factor price data on wages, rental rates of capital and land are available from a range of Japanese historical studies.

Our test values the factor content of Japan's trade in each year of the early trading period 1865-1876 at the corresponding autarky factor price vector during the late autarky period of the mid-1850s. Since the inner product is positive in every trading year, our results provide strong empirical support for the general Heckscher-Ohlin-Deardorff (HOD) formulation. Our test results are robust to adjustments for trade imbalances and substantial international differences in the productivity of land used to produce wool.

In section 2 we discuss the general formulation of the Heckscher-Ohlin theorem as formulated by Alan V. Deardorff (1982). Section 3 discusses the natural experiment of Japan, the empirical domain and the data sources for the construction of the factor content of trade and the autarky factor prices. Section 4 contains the empirical results and investigates robustness. We conclude in section 5.

2. The price formulation of the Heckscher-Ohlin Theorem

Consider a neoclassical economy, called home, where *m* factors are potentially employed in the production of *n* goods. Technology is characterized by a technology set K consisting of feasible pairs (**V**, **Y**), where $\mathbf{Y}=(Y_1,\ldots,Y_n)$ is a vector of production levels resulting from the factor employment vector $\mathbf{V}=(V_1,\ldots,V_m)$.[6] The economy's fixed factor endowment vector is given by $\mathbf{V}^0$ and equilibrium factor prices are denoted by $\mathbf{w}=(w_1,\ldots,w_m)$.

[6] We assume that the technology set fulfils all the standard neoclassical assumptions, such as closedness and convexity, which are required to ensure the existence of an autarky and trade equilibrium.

Consumer demands are denoted by $\mathbf{C}=(C_1,\ldots,C_n)$. Consumers respond to domestic goods prices, denoted by $\mathbf{p}=(p_1,\ldots,p_n)$, and are assumed to conform in the aggregate to the weak axiom of revealed preference[7]:

$$\mathbf{p}^1\mathbf{C}^1 \geq \mathbf{p}^1\mathbf{C}^2 \;\Rightarrow\; \mathbf{p}^2\mathbf{C}^1 > \mathbf{p}^2\mathbf{C}^2. \qquad (1)$$

This result has the standard interpretation that if the consumption point $\mathbf{C}^1$ was chosen at the price regime $\mathbf{p}^1$ at which $\mathbf{C}^2$ could have been chosen, then if $\mathbf{C}^2$ was chosen at the price regime $\mathbf{p}^2$, $\mathbf{C}^1$ could not have been affordable.

We consider two regimes, autarky and open trade. The superscripts *a* and *t* identify the variables associated with the two regimes. In autarky, production coincides with consumption, or $\mathbf{Y}^a=\mathbf{C}^a$, and autarky goods and factor prices $\mathbf{p}^a$ and $\mathbf{w}^a$ are such that production is feasible, there is no excess demand and producers maximize profits. Profit-maximization implies that

$$\mathbf{p}^a\mathbf{Y}^a-\mathbf{w}^a\mathbf{V}^0 \;\geq\; \mathbf{p}^a\mathbf{Y}-\mathbf{w}^a\mathbf{V} \quad \text{for all } (\mathbf{V},\mathbf{Y}) \text{ in } K. \qquad (2)$$

In the trade equilibrium, the consumption vector $\mathbf{C}^t$ will generally be different from the economy's production vector $\mathbf{Y}^t$. The difference is the net import vector $\mathbf{T}=\mathbf{C}^t-\mathbf{Y}^t$. The trade equilibrium is characterized by vectors of domestic goods and factor prices $\mathbf{p}^t$ and $\mathbf{w}^t$ such that production and trade are feasible, there is no excess demand and producers maximize profits. In the trade equilibrium, profit maximization implies that

$$\mathbf{p}^t\mathbf{Y}^t-\mathbf{w}^t\mathbf{V}^0 \;\geq\; \mathbf{p}^t\mathbf{Y}-\mathbf{w}^t\mathbf{V} \quad \text{for all } (\mathbf{V},\mathbf{Y}) \text{ in } K. \qquad (3)$$

Since our focus is on the factor content of trade, we need to be more specific about technology and the economy's trading partners. We denote the economy's trading partners as the rest of the world (ROW). As suggested by Deardorff (1982), in a trading equilibrium without international factor price equalization there are several alternatives for defining the factor content

[7] This characterization of aggregate preferences is more general than assuming the existence of a community utility function.

of trade. In this paper we consider the most general formulation, which calculates the factor content of trade at the location of actual production.[8] Ethier (1984, p. 175) has pointed out that measuring the factor content of trade according to the country of origin of goods "avoids the problems introduced by higher-dimensional analogs of factor-intensity reversals, which must be assumed away in the 2x2 case."

It is convenient to write the economy's trading vector into its individual gross import and export components, or $\mathbf{T}=(\mathbf{M},-\mathbf{X})$[9]. The actual factor content of trade is then defined as $\mathbf{F}=\breve{\mathbf{A}}\,\mathbf{T}=\mathbf{A}^{\mathbf{ROW}}\mathbf{M}-\mathbf{A}\mathbf{X}$, where $\breve{\mathbf{A}}=(\mathbf{A}^{\mathbf{ROW}}, \mathbf{A})$ and **A** contains input requirements for home's exports and $\mathbf{A}^{\mathbf{ROW}}$ contains the input requirements of foreign exports to home at the location of exports. The matrix **A** of domestic unit input coefficients maps the economy's gross export vector **X** into the factor content of gross exports **AX**. The calculation of the factor content of gross imports $\mathbf{A}^{\mathbf{ROW}}\mathbf{M}$ is more complicated as it depends on the location of foreign production. If all imports come from a single foreign economy, $\mathbf{A}^{\mathbf{ROW}}$ is just the matrix of foreign input coefficients. If the imports come from multiple countries, it is necessary to trace back the complete production history of each imported good and add up all factors used in production plus those used in intermediate inputs to its production.

The standard Heckscher-Ohlin formulation assumes identical technologies across countries. Our formulation is a bit more general. Although we allow for technological differences, these differences are not allowed to be too large. This is accomplished by assuming

[8] Alternatively, the factor content can be calculated using the domestic technology matrix or be based on the actual content of consumption. However, Deardorff (1982, p. 689) and Ethier (1984, p.174) have stressed that the path to a general formulation of Heckscher-Ohlin requires the use of technologies based on the country of origin of traded goods.

[9] This exploits the model's property that a good is either exported or imported in equilibrium; so that there is no two-way trade.

that if the economy's endowment vector $\mathbf{V}^0$ were augmented by $\mathbf{F}$, then it would be technologically feasible to produce the trade consumption vector $\mathbf{C^t}$ domestically. Formally,

$$(\mathbf{V}^0+\mathbf{F}, \mathbf{C}^t) \text{ is in } K. \qquad (4)$$

It is clear that (4) will hold if home and ROW have identical technologies since F will yield an augmentation of domestic endowments which is sufficiently large to produce the imported goods domestically with the resource savings from exports. However, for given trade flows, uniform higher factor productivity levels abroad might result in an augmentation of domestic endowments which is not sufficient enough to produce $\mathbf{C^t}$ domestically. Assumption (4) imposes a restriction on technological differences which prevents this from happening.

Balanced trade occurs at the world price vector $\mathbf{p}^w$, i.e. $\mathbf{p}^w\mathbf{T}=0$, which can be different from the domestic price vector $\mathbf{p}^t$ because of trade restrictions. What needs to be assumed is that trade is, on average, more taxed than subsidized, which can be written as:

$$(\mathbf{p}^t\text{-}\mathbf{p}^w)\mathbf{T} \geq 0. \qquad (5)$$

The intuition for this is that trade taxes, although reducing the volume of trade, do not interfere with the comparative advantage pattern of trade prediction. In contrast, trade subsidies can be so large that they prompt trading patterns that override underlying factor scarcity.[10] We are now in the position to state what we might call the Heckscher-Ohlin-Deardorff (HOD) Theorem.

<u>Heckscher-Ohlin-Deardorff Theorem:</u>

Consider a single economy characterized by (1)-(5). The economy's autarky factor price vector interacted with home and foreign input coefficients impose a refutable prediction on the economy's commodity pattern of trade, such that $(\boldsymbol{w}^a \check{\boldsymbol{A}})\boldsymbol{T} \geq 0$.

<u>Proof:</u> The balanced trade condition and (5) imply $\mathbf{p}^t\mathbf{T} \geq 0$. Applying autarky production to the right-hand side of (3) yields $\mathbf{p}^t\mathbf{C^t}$ - $\mathbf{p}^t\mathbf{T}$ -$\mathbf{w}^t\mathbf{V}^0 \geq \mathbf{p}^t\mathbf{C^a}$ -$\mathbf{w}^t\mathbf{V}^0$. Rearrangement gives rise to $\mathbf{p}^t\mathbf{C^t} \geq$

[10] Europe's common agricultural policy provides a classic example.

$\mathbf{p}^t\mathbf{C}^\mathbf{a}$**.** The weak axiom of revealed preference (1) implies then that $\mathbf{p}^a\mathbf{C}^\mathbf{t} > \mathbf{p}^a\mathbf{C}^\mathbf{a}$. Employing (2) and (4), we obtain $\mathbf{p}^a\mathbf{C}^a\text{-}\mathbf{w}^a\mathbf{V}^0 \geq \mathbf{p}^a\mathbf{C}^t \text{-}\mathbf{w}^a(\mathbf{V}^0+\boldsymbol{F})$, which implies that

$\mathbf{w}^a\breve{\boldsymbol{A}}\,\boldsymbol{T} \geq \mathbf{p}^a\mathbf{C}^\mathbf{t}\text{-}\mathbf{p}^a\mathbf{C}^\mathbf{a} > 0$.

Applying the logic of the theorem to the rest of the world, we obtain the following corollary:

Corollary:

Consider two economies characterized by (1)-(5). The interaction between autarky factor price differences and home and foreign input coefficients yields a restriction on the commodity pattern of trade, such that $(\mathbf{w}^a - (\mathbf{w}^a)^{ROW})\breve{\mathbf{A}}\,\mathbf{T} \geq 0$.

Proof: The corollary follows from adding the two constraints and exploiting the symmetry implied by calculating the factor content with the techniques of the exporting country, i.e. $\mathbf{F}^{\mathbf{ROW}} = \text{-}\mathbf{F}$.

Several comments are in order. First, the proof of the theorem shows that the existence of the gains from trade, as formulated by the weak axiom of revealed preference, is a key critical condition for the derivation of the prediction. Second, the inequality from the theorem holds for different definitions of the factor content of trade. Using the tools of factor content functions for a single economy, Neary and Schweinberger (1986) derive it by measuring exports and imports with domestic technologies. However, Deardorff (1982) shows that a multi-country formulation can only be established if the factor content of trade is measured using the technological coefficients of a good's country of origin.

The corollary provides the simplest multi-country formulation of the Heckscher-Ohlin theorem by aggregating home's trading partners into ROW. If for example, ROW consisted of say three sub-economies ROW_1, ROW_2 and ROW_3, one would obtain four restrictions from the H-O-D theorem which could be stacked together to obtain a single multi-country Heckscher-

Ohlin prediction, as formulated in Deardorff (1982, Corollary 1, p. 689). However, since we do not observe multiple economies in autarky, such a formulation is not testable.

The Heckscher-Ohlin-Deardorff Theorem applies to *any* economy observed under autarky and trade. For that reason, any economy for which we can observe autarky prices and for which we are able to measure the factor content of trade using the technology at the location of production is a candidate for testing its empirical validity. The correct measurement of the factor content of trade ensures that the test is conducted in a proper multi-country setting.

Since the ROW has been in isolation relative to Japan, one might be inclined to consider testing the restriction from the corollary. However, this would not only require the construction of average factor prices in the ROW, which is formidable task, but also ignore the trading relationship among the economies within the ROW.

An empirical validation of HOD provides a major step forward in testing a general specification of Heckscher-Ohlin. By measuring the factor content of trade at the location of actual production, HOD predicts a country's pattern of international trade based on the interaction between autarky measures of factor scarcity and home and foreign factor input requirements. Ethier (1984, p.175) emphasizes that the prediction that a country will on average export goods which make relatively intensive us of their relatively abundant factors is a proper higher-dimensional extension of the 2x2 price version of Heckscher-Ohlin.

3. Empirical implementation and construction of data

3.1 Experimental conditions and domain

The static trade model requires that the Japanese economy meets four basic conditions during the period of autarky from which data are collected (ca. 1845 to 1859) and the early trade period (1860 to 1876):

1) Markets for goods were competitive under autarky and trade.

2) Japan produced relatively homogeneous products in small scale production units, ruling out other explanations for Japan's trading patterns such as increasing returns to scale or imperfect competition.

3) After its opening up, the economy operated under a trade regime in which the country's exports did not receive substantial subsidies.

4) The factor prices observed during autarky were outcomes of competitive market conditions, including factor mobility and the absence of market power.

The recent historical literature on Japan summarized in Hayami, Saito and Toby (2004) provides evidence that the Japanese economy met conditions (1) and (2). Most tradable goods were produced by farmer households and small-scale merchants. With the exception of a few coal and copper mines, traditional Japanese technologies ensured that metals and other processed raw materials would be produced in small workshops or firms. Bernhofen and Brown (2004, p. 58) discusses the absence of export subsidies (assumption (3)) during the early period of open trade.

The fourth assumption has been the subject of recent research on factor markets, particularly during the late Tokugawa era (roughly 1820 to 1868).[11] This research has challenged the view of Marxist scholars that feudal restrictions imposed by the Tokugawa regime on land and labour markets were fully binding until the Meiji era reforms of the 1870s and later. Saitō (2009, p. 174) notes that although the formal transfer of landholding rights remained difficult to

[11] The Tokugawa family ruled Japan as a quasi-military regime until the Meiji Revolution of 1868, which reasserted the central role of the emperor and initiated Japan's modernization.

carry out, leasing arrangements meant that “tenancy came to function as if there had existed a genuine lease market for land.” The pace of economic change hollowed out the regulations from the 17th century that attempted to limit the movement of the population as well as the restrictions on entry imposed by the urban guilds of Osaka. As Saitō (2009, p. 186) notes, by the first half of the nineteenth century there was “a well-integrated labour market between the peasant farm household and non-farm sectors within a regional setting.” Although Saitō argues that the integration of the two major regional markets appears to have been most effective at the level of white collar employment, real wage series for unskilled workers in Kyoto (in the west) and skilled workers in a town outside of Tokyo (in the east) were highly correlated over the period 1820 to 1853 (see Saitō [1998]).

Saitō and Settsu (2006) and Toby (2004) summarize historians’ understanding of capital markets in Japan during the late Tokugawa period. Borrowing and lending by feudal lords did take place and the lease market in land offered a way for landowners to receive credit. The question is whether financial intermediation also took place. Toby (2004)‘s detailed examination of the ledgers of a family engaged in lending in a small town outside the main urban areas offers one answer. Based upon the levels and trends in quoted interest rates for interbank borrowing, the geographic reach of the family’s borrowing and lending and evidence from other studies, he concludes that “a national credit market was in play”(Toby, 2004, p. 319).

The theoretical prediction is based on a static model combining data under autarky and trade, but without accounting for the passage of time. However, since autarky and free trade are observed at different points in time, a correct empirical inference requires that the economy’s factor scarcity conditions were not affected in the transition from autarky to the early free trade period. Furthermore, while the static theory necessarily assumes balanced trade, an actual economy will typically experience periods of imbalanced trade during particular time periods.

These considerations lead us to the following two identification conditions:

5) The observed sign of the inner product is caused by underlying factor scarcity and not by an underlying trade deficit.

6) During the transition from autarky to free trade the economy did not experience changes in preferences, technologies or the composition of its endowments.

If the country is running a trade deficit, then the sign of the inner product might just reflect its excess factor imports rather than Heckscher-Ohlin forces. This is most easily seen by considering the stark hypothetical case where the country only imports but does not export anything. In such a scenario the autarky value of net imports is positive, but this is not informative about Heckscher-Ohlin. Fortunately, Japan's trading pattern during the first years of trade included some years of surplus and other years of deficits so that we can investigate robustness regarding trade imbalances. We will discuss our strategies of how we deal with trade imbalances when we present our results in section 4. This brings us then to the second identification condition.

The transition period from autarky to open trade exposed the Japanese to encounters with western preferences and technology. For the best empirical implementation of the analysis, we focus on the first period of open trade (1860 to 1876). During this period, preferences were reasonably stable and the economy did not experience significant changes in technologies. Despite the enthusiasm of some elites for western culture and institutions after the Meiji restoration of 1868, preferences for consumption remained largely unchanged during the first two decades of open trade. Uchida (1988) and Tamura (2001) provide evidence that this was the case for most cotton and woolen textile imports. Machine-spun yarns were readily adapted to Japanese manufacturing methods; imports of cloth were adapted to Japanese tastes in clothing. The marketing strategies of western merchants assumed continued use of traditional clothing.[12]

The unique historical circumstances of the Japanese case precluded the rapid adoption of western technologies and transportation systems before the 1880s. As Pauer (1987) notes, Japan's labour force initially lacked the skills to readily adopt the steam- and iron-based technologies of the west. By the close of the test period (1876), the Meiji government and some western investors had introduced western methods in government-run armories and a handful of coal, copper and gold and silver mines employing at most a few thousand workers.[13] Land transportation continued to rely upon pack horses. The largest change occurred in coastal shipping, with the introduction of some steamships and western sailing vessels.[14] Even incremental changes in business organization such as the creation of large-scale cocoon reeling establishments with specialized female labour took place slowly.

Population growth was modest in the years following the opening up, and Japanese historians do not report any notable changes in the age structure or sex composition of the population. There was no sizeable emigration or immigration, nor were there substantial imports of capital goods.

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[12] See German Consul in Hiogo (1873). The German Consul in Edo (1873) reports that the use of woolen cloth for western dress was restricted to government uniforms of various kinds and some of the wealthiest classes.

[13] British consuls in the treaty ports complained repeatedly that the government's hostility to foreign ownership prevented the much-needed modernization of the mining and metallurgy sectors. See the summary report by Plunkett (1875).

[14] Unlike in Latin America, the Anglo-Saxon regions of recent settlement or colonial Africa, foreign capital played a very circumscribed role in the establishment and construction of modern transportation systems in Japan.

3.2 Hypotheses

We exploit the circumstances of Japan's opening up to trade to test the following hypothesis about the sign of Japan's vector of net factor imports valued at autarky factor prices:

$$H_0:\ \mathbf{w^a F^i} = \mathbf{w^a}\ (\mathbf{\breve{A}}\ \mathbf{T^i}) \geq 0, \qquad (6)$$

where $\mathbf{\breve{A}}$ is the technology matrix during the early free trade period and $\mathbf{T^i}$ is the vector of net imports in each test year i (i=1865,…,1876). To our knowledge, no other theory exists that suggests an alternative restriction on the economy's factor content of net imports. For that reason, we postulate randomness as the alternative hypothesis:

$$H_1:\ \mathbf{w^a F^i} \text{ is random with } \Pr(\mathbf{w^a F^i} < 0) = 0.5 \qquad (7)$$

In order to make a probability statement about the alternative hypothesis, we assume that in the case of randomness it is equally likely to obtain a positive as a negative sign. Assuming further that the 'yearly drawings' are independent and stem from the same distribution, we can then calculate the smallest level of significance for which the data would allow us to reject the randomness hypothesis H_1.

*3.3 Construction of the trading vector **T**, technologies **Ă**, and autarky price vector $\boldsymbol{w^a}$*

The Data Appendix 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. Although open trade officially began on July 4, 1859, the Tokugawa regime only abandoned efforts to limit the export of Japan's most important exports of silk and silkworm eggs in 1864 after western military action. Fort that reason, the tests of the hypothesis use trade data from 1865 through 1876.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.[15] For example, ten percent 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, 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 percent 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 $\breve{\mathbf{A}}$ matrix and the trade vector. Since the production location of all exports is in Japan, the remainder of the paper denotes the home technology matrix with $\mathbf{A}^{\mathbf{J}}$.

A review of the technologies for both Japan and the main source countries for its imports suggested that an $\breve{\mathbf{A}}$ matrix that was defined over five factors of production 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.[16] For that reason, the matrix uses three categories of labour measured in days: 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

[15] The Data Appendix lists the specific sources for the surveys of trade conditions conducted by Prussian, Austro-Hungarian and Swiss observers in the 1860s and the consular reports from Germany, the United States, Great Britain and Belgium for the 1860s and 1870s.

[16] The Data Appendix provides a more detailed discussion of the rationale for and measurement of the five factors.

power of 1854-1857.[17] 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 $\mathbf{A}^{\mathbf{J}}$ matrix included 23 different products; about 80 percent 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. Coal, copper, various maritime products, mushrooms, camphor and vegetable wax accounted for almost all of the rest. The construction of the $\mathbf{A}^{\mathbf{J}}$ 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 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.

The presence of joint production arises within the context of the sericulture industry. For example, only about 80 percent of the output of cocoons in the Gunma prefecture were of high enough quality to be sold as raw silk. The production of raw silk resulted in a number of

[17] 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).

byproducts, including waste cocoons, pierced cocoons, tama or dupioni silk, noshi silk and floss silk. During the early trading years, most of these byproducts were retained for domestic use as wadding or to be processed further into lower-quality silk products. To avoid underestimating the resources going towards silk exports, input requirements were adjusted upwards on the assumption that all production was high quality cocoons and silk. The small fraction of the byproducts that was exported could then be treated as pure joint products.[18]

For the $\mathbf{A^J}$ 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.[19] Finally, all measured land is assumed to be useable as cropland, or its equivalent in Japan, dryfield land.[20]

The upper panel of Table I shows selected columns of the $\mathbf{A^J}$ matrix for the nine most important exports of Japan during the test period. Sericulture dominates the resource intensity of Japan's exports. The unit resource requirements for raw silk are about 10 to 50 times those for tea. Maritime products used the lowest amount of resources by weight.[21] The other striking feature of panel A is the importance of male unskilled labour for all products with the exception of coal and copper, which relied upon skilled workers for both mining and the processing and smelting of ore.

[18] The share of these byproducts retained for domestic use was larger than the share of raw silk, which means that they essentially required no additional resources.
[19] See Saitō and Settsu (2006) for a review of the available evidence, which places the range in 12 to 15 percent.
[20] Japanese land consisted of dryfields, which were used for crops such as cotton, soybeans and indigo, and paddy land, which was used for rice.
[21] By weight, market prices for silk were on the order of 15 times the price of tea and 40 or 50 times the price of dried cuttlefish. Strictly speaking, the coefficient on land for sericulture overstates its land intensity. Syrski (1872, pp. 230-231) notes that mulberry trees were traditionally grown on marginal land such as the borders of fields that would not be used as cropland. Only by the 1890s did mulberry begin to compete with other crops for the use of dryfields in the silk-producing Gunma prefecture. See (Iinkai, 1988 #1183}.

The construction of the $\mathbf{A}^{\mathbf{ROW}}$ matrix took account of the production location of the largest supplier to the Japanese market.[22] This approach took full account of the heterogeneity of production conditions across supplier countries and within individual 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 $\mathbf{A}^{\mathbf{ROW}}$ 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 $\mathbf{A}^{\mathbf{J}}$ 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. Finally, land was treated as equivalent to Japanese dryfields, although the increased reliance of European producers of woolens on sheep grown on the pampas of Argentina and the semi-desert grazing lands of Australia suggest that this assumption will require a closer look. Input requirements could be ascertained for over 81 percent 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.

The lower panel of Table I provides selected columns of the $\mathbf{A}^{\mathbf{ROW}}$ matrix. The bottom rows include the import shares for the most important imports along with the source country (or countries) for those imports. About one-third of imports consisted of products of the cotton textile industry. These industries used mostly unskilled male labour and unskilled female labour.

[22] Typically, the largest supplier amounted to seventy or eighty percent of the Japanese market.

The higher capital intensity of woolens reflects the more widespread use of hand looms and the lower productivity of spinning machines compared with cotton textiles. The relatively high input requirement of land stems from the large amount of land required to raise sheep; all-woolen heavy-weight and medium-weight woolens, such as military cloth and camlets, were particularly land-intensive. Lightweight woolens generally used a mix of cotton and worsted yarn, which accounts for the reduced importance of land.

Finally, the vector of factor prices $\mathbf{w^a}$ meets two criteria. First, it takes full account of potential differences in the two most important economic regions of autarky Japan: the Kinai in the west (centered on Kyoto and Osaka) and the Kantō, centered on Edo (Tokyo) in the east. The slightly higher wages in the west were chosen as the upper bound on autarky wages for Japan. Since the subsequent analysis will show that Japan was a net exporter of labour, use of the upper bound should bias the results against acceptance of the hypothesis. Land did vary in quality, and official assessments of land identified five quality levels as well as whether it was used as paddy land or dryfields. Detailed land price and rent evidence that includes information on both characteristics is available for several locations in the west, 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.[23] This adjusted rent most closely reflects the opportunity cost of land used for the production of soybeans and other grains, but understates the rent for land used for the much larger imports of rice and cotton. Since

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

we will see that Japan was a net importer of land, use of this lower-bound estimate should bias the test against acceptance of the hypothesis.

4. Empirical findings

4.1 Core results

The results of the test of the Heckscher-Ohlin hypothesis (6) are found in Table II for each test year. The five upper rows of each panel show the autarky valuation of each factor flow and the final row provides the summation of these values. Throughout the sample period, net exports of unskilled (and to some extent, skilled) labour and net imports of land dominated factor flows.   For each test year, the final row of the upper panel of Table II provides the calculation of $\mathbf{w^a A^J X^i}$, or the autarky valuation of the factor services embodied in exports. The value of factor exports ranges between 1.7 and 4.8 million gold ryō. Changes in the export of sericulture products account for most of the year-to-year variation. Despite the importance accorded to female labour in historical accounts of the sericulture industry, male labour played a much larger role in factor exports.

Panel B of Table II provides $\mathbf{w^a A^{ROW} M^i}$, which is the autarky value of the factor services of foreign imports. Imports of unskilled male and female labour are almost evenly balanced throughout the period. The calculated imports of land are substantial and would have equaled from one-tenth to one-third of Japan's estimated arable land in 1874 (See Le Gendre [1878, Appendix Table]).[24]

Panel C of Table II includes the autarky valuation of the net flow of factors, $\mathbf{w^a F^i}$. Japan was generally a net exporter of skilled and unskilled male labour and a net exporter of capital in all years except for 1875 and 1876. Poor harvests in 1869 and 1870 led to a surge in imports of

[24] Unlike the scenarios laid out in Heckscher's original 1919 article and the subsequent literature on the 19th century Atlantic economy, which focused on meat and wheat, these imports primarily involved the importation of land-intensive woolens and, to a lesser extent, cotton yarn and cloth. (See Heckscher [1991]).

unskilled labour through imports of rice and legumes; Japan was a net *importer* of unskilled male labour in 1870. For several years, Japan was a net exporter of capital, although there are several years for which the trade in capital was almost balanced. In addition, it was a net importer of female labour for nine of the eleven test years and a net importer of land in each sample year. A comparison with two recent appraisals of the early trading pattern of Japan suggest that using a theory-based approach to measure the pattern of trade holds considerable promise. Our findings on the importance of imports of land contrast with Yasuba (1996), who argues that the importance of primary products such as silk and tea in Japan's exports reflects a comparative advantage in land-intensive exports. The results also offer a challenge to Williamson (2000), who correctly surmises that Japan's exports were labour-intensive and its imports were land-intensive, but who overlooks the importance of the net imports of female labour and who also contends that Japan was a net importer of capital.

The final row of Table II contains the test values of $\mathbf{w^aF^i}$ which reveal a positive sign in each of the eleven sample years. Under the maintained hypothesis that the annual data are drawn independently from the same distribution, we can test the Heckscher-Ohlin hypothesis H_0 against the randomness hypothesis H_1. For eleven positive signs in a sample of eleven, the p-value, defined as the smallest level of significance for which we can reject H_1 in favor of H_0 is about 0.05 percent. These findings provide strong evidence for the Heckscher-Ohlin prediction.

4.2 Evaluation of Robustness

Although the results appear to provide unambiguous support for the autarky-price version of the Heckscher-Ohlin hypothesis, an examination of two important complications is in order. First, for each of the eleven test years, Japan's trade was not balanced. The trade imbalance violates the fifth constraint on the empirical domain of the test, which asserts balanced trade. In addition, the assumption that all land is of equivalent quality most likely overstates the actual amount of land embodied in Japan's imports. Taking account of these two issues leaves the main qualitative results intact.

The top row of Table III presents the ratio of recorded exports to imports (or $(\frac{\boldsymbol{pX}}{\boldsymbol{pM}})^i$). Trade deficits occurred during 1867 and over the period 1869 through 1875. 1865 and 1868 saw substantial trade surpluses and 1876 recorded a modest trade surplus. While trade surplus years are of minor concern as they will bias the results against the Heckscher-Ohlin prediction, years of a trade deficit my bias the results in its favor. To test for robustness for the years in which there is a trade deficit, we adjust the factor services embodied in imports to a level consistent with balanced trade, or $\breve{M}^i = \left(\frac{\boldsymbol{pX}}{\boldsymbol{pM}}\right)^i M^i$. This approach requires us to assume that Japanese preferences are homothetic so that one can scale down imports to evaluate the factor content of trade at an adjusted import vector that satisfies the balanced trade condition.[25] The corresponding test value for any one year is $\boldsymbol{w}^a\widetilde{\boldsymbol{F}}$, where $\widetilde{\boldsymbol{F}} = \breve{A}\left(\widetilde{\boldsymbol{M}} - \boldsymbol{X}\right)$. Panel A of Table III presents the net imports of factors under the assertion of balanced trade in years of a trade deficit. The imposition does not fundamentally change the sign of the inner product of autarky factor prices nor does it modify the pattern of the factor content of trade.

The assumption that all land is of equal quality raises a more fundamental issue of measurement. Most of Japan's net imports of land presented in Table II were embodied in its imports of woolen cloth, which was not produced in Japan because of the absence of land suitable for grazing sheep. In European countries, raising sheep for the most part used a mix of pasture land for grazing during the warmer seasons and cropland land to provide feed during the

[25] The adjustment uses the values of exports and imports for which it is possible to measure the factor trade (about 97 percent of exports and 81 percent of imports).

remainder of the year. Senkel (1901) notes that by the 1860s and the beginning of the early trade period in Japan, woolen industries in Europe were increasingly substituting wool imported from the newly-settled areas of the southern hemisphere (Argentina, Uruguay, South Africa, Australia and New Zealand) for domestic wool. The new entrants to the market relied exclusively on extensive methods of raising sheep, where sheep remained on large pastures throughout the year and sheep farmers provided little, if any additional feed. Although well-suited for grazing sheep, much of this land was semi-arid to arid and often hilly; it was thus of much lower quality than the arable land used to grow cotton, rice and other products imported into Japan. If the land required to keep one sheep was about 0.2 acres in Germany, it was 0.6 acres or more in Argentina and 2.5 acres in the Australian states of Victoria and New South Wales (and highest in the most arid and remote regions of both Argentina and Australia).

To arrive at a "dryfield equivalent" for the land used in raising sheep, information on rents for arable and pastoral land was collected from the three European exporters of woolens and the two largest suppliers from the southern hemisphere, Argentina and Australia. For example, the rent on good quality pasture land in Australia that was sufficient for 0.4 sheep rented for about 5 pence per acre. The rent per acre for good quality farmland in the United Kingdom during the same period was about 216 pence per acre. The dryfield equivalent of Australian land used in the production of British woolens is thus estimated to be only two percent (5/216) of the actual acreage used, and in Argentina it is 10 percent.[26] Panel B of Table III presents the result of adding a correction for the quality of land to the results presented in Table II. Overall, woolens accounted for about 38 percent of the adjusted imports of land, cotton

[26] Additional details on the calculation and the sources used are in the Data Appendix. This approach overestimates quality differentials. Argentina's nineteenth-century focus on pastoral agriculture (wool and beef) gave way to a substantial expansion of wheat farming after 1900 and similar developments marked Australia's emergence as an important exporter of wheat.

textiles another 33 percent, and sugar, rice and raw cotton the remainder. The results in Panel B suggest that the essential lesson remains the same: Japan's pattern of trade is consistent with the Heckscher-Ohlin hypothesis in all 11 test years.

The large export surpluses during 1865 and 1868 and the more limited coverage of imports (which included cannons and ships) during these years would necessarily lead to an underestimate of the Heckscher-Ohlin test statistic. The final results in Panel C of Table III take account of both adjustments for differences in land quality and imbalanced trade. Japan was a net exporter of skilled and unskilled male labour and capital. Most important for its pattern of trade in resources was its importation of land. In each of the 11 test years, the value of $\boldsymbol{w}^{a}\widetilde{\boldsymbol{F}}^{i}$ is positive.

5. Concluding remarks

In his *Foundations of Economic Analysis*, Paul Samuelson put economic theory on a solid scientific grounding by developing comparative statics methods aimed at deriving operationally *meaningful theorems*. Samuelson (1947, p.4) defines a meaningful theorem as "a hypothesis about empirical data which could conceivably be refuted, if only under ideal conditions… [and] it is meaningful because under ideal circumstances an experiment could be devised whereby one could hope to refute the hypothesis." A long line of research that applies comparative statics methodology to international trade has shown that Ohlin's (1933) hypothesis on the relationship between autarky factor prices and international trade can be formulated as an operationally meaningful theorem. This was initially accomplished for the two-country, two-factor, two-commodity world familiar from undergraduate textbooks in international trade. Subsequent research by Deardorff (1982) has formulated a refutable Heckscher-Ohlin proposition for a single economy that holds under general conditions regarding dimensionality and assumptions about the economy's trading partners.

This paper argues that Japan's economy before and after its 19th century move from autarky to free trade provides the "ideal conditions" where the Heckscher-Ohlin theorem "could conceivably be refuted." The case of Japan conforms to all the critical assumptions of the autarky price formulation of the Heckscher-Ohlin theorem. The historical circumstances of its opening up to international trade ensure that it meets the identification conditions necessary to test the theorem. The historical sources allow us to construct a technology matrix based on disaggregated data of input requirements at the location of production. Combining these data with matching commodity trade flows and autarky factor prices permitted us to test the Heckscher-Ohlin hypothesis. We were not able to reject the hypothesis in any of the sample years. This is certainly good news for the neoclassical trade model and to those who have contributed to its formulation since Ohlin.

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Table I: Selected Columns of the Ă Matrix

Panel A: Exports ($\mathbf{A^J}$ matrix)

	Silk	Silkworm eggs	Tea	Copper	Seaweed	Dried Cuttlefish	Coal	Vegetable Wax	Mushrooms
Skilled Male	2.225	0.184	0.274	0.330	0.005	0.015	3.654	0.000	0.000
Unskilled Male	19.077	1.235	0.353	0.325	0.011	0.020	1.537	0.227	0.585
Female	6.434	0.118	0.126	0.035	0.016	0.000	0.023	0.000	0.000
Capital (ryō)	0.087	0.005	0.005	0.011	0.000	0.000	0.001	0.001	0.000
Land (tan)	0.368	0.021	0.014	0.000	0.000	0.000	0.004	0.000	0.015
Share of X	0.400	0.120	0.240	0.024	0.020	0.012	0.019	0.010	0.011
Unit	catty	card	catty	catty	catty	catty	ton	catty	catty

Panel B: Imports ($\mathbf{A^{ROW}}$ matrix)

	Cotton Yarn	Grey Cotton Cloth	Finished Cotton Cloth	Light Woolens	Heavy Woolens	Medium Woolens	Rice	Brown Sugar	White Sugar	Iron Mfcs	Raw Cotton
Skilled Male	0.016	0.004	0.008	0.022	0.196	0.045	0.000	0.000	0.000	0.018	0.000
Unskilled Male	0.317	0.024	0.071	0.070	0.636	0.148	0.019	0.038	0.098	0.005	0.848
Female	0.370	0.019	0.033	0.063	0.285	0.113	0.006	0.065	0.167	0.013	0.532
Capital (ryō)	0.006	0.001	0.003	0.099	0.093	0.162	0.000	0.001	0.002	0.003	0.001
Land (tan)	0.059	0.005	0.012	0.032	0.307	0.127	0.001	0.010	0.026	0.000	0.018
Share of M	0.138	0.112	0.082	0.072	0.047	0.032	0.081	0.065	0.028	0.026	0.021
Unit	catty	yard	yard	Yard	Yard	Yard	catty	catty	catty	catty	catty
Source	Great Britain	Great Britain	Great Britain	Great Britain France Germany	Germany Great Britain	Great Britain	China	Formosa	Formosa	Great Britain	China

Source: For a detailed discussion of the sources, please see the Data Appendix.
Notes: All labour requirements are measured in days. According to Bavier (1874, p. 73), a card of silkworm eggs weighed about 0.8 lbs. A catty weighed 1.33 pounds. One tan is about 0.25 acres. The grey cotton cloth is an 8.25 lb. bolt of shirtings. The example for a

finished cotton cloth is for a medium weight dyed cloth such as dyed shirtings. The shares of exports and imports refer to total trade over the sample period 1865 through 1876.

Table II: The Pattern of Japan's Factor Trade in the Early Years of Open Trade (in millions of ryō)

	Factor Price	1865	1867	1868	1869	1870	1871	1872	1873	1874	1875	1876
Panel A: Factor Exports												
Skilled male	0.053	0.32	0.32	0.27	0.22	0.30	0.48	0.48	0.44	0.50	0.52	0.59
Unskilled male	0.031	1.06	0.61	0.86	0.60	0.64	1.08	0.89	1.02	0.97	1.06	1.58
Female	0.019	0.20	0.12	0.17	0.12	0.12	0.21	0.16	0.20	0.18	0.21	0.30
Capital	1.000	0.75	0.48	0.63	0.48	0.59	1.05	1.02	0.92	0.96	0.99	1.21
Land	1.040	0.69	0.18	0.59	0.41	0.46	0.74	0.59	0.71	0.72	0.78	1.14
Total $\mathbf{w^a A^J X^i}$		**3.01**	**1.71**	**2.52**	**1.83**	**2.11**	**3.56**	**3.13**	**3.28**	**3.33**	**3.56**	**4.81**
Panel B: Factor Imports												
Skilled male	0.053	0.08	0.11	0.10	0.08	0.07	0.06	0.09	0.08	0.07	0.13	0.09
Unskilled male	0.031	0.14	0.33	0.25	0.46	0.76	0.57	0.35	0.39	0.55	0.50	0.48
Female	0.019	0.07	0.16	0.14	0.18	0.30	0.26	0.23	0.24	0.32	0.31	0.30
Capital	1.000	0.60	0.45	0.29	0.39	0.58	0.77	0.76	0.91	0.91	1.64	1.31
Land	1.040	24.18	12.75	7.73	7.59	8.04	9.26	10.10	12.25	7.44	8.83	6.66
Total $\mathbf{w^a A^{ROW} M^i}$		**25.08**	**13.81**	**8.51**	**8.71**	**9.75**	**10.92**	**11.54**	**13.87**	**9.29**	**11.40**	**8.84**
Panel C: Net Factor Imports												
Skilled male	0.053	-0.24	-0.21	-0.17	-0.14	-0.23	-0.42	-0.39	-0.36	-0.42	-0.40	-0.50
Unskilled male	0.031	-0.92	-0.28	-0.61	-0.14	0.12	-0.51	-0.53	-0.63	-0.42	-0.56	-1.10
Female	0.019	-0.13	0.05	-0.03	0.07	0.18	0.05	0.07	0.04	0.13	0.10	0.00
Capital	1.000	-0.15	-0.03	-0.34	-0.08	-0.01	-0.28	-0.26	-0.00	-0.05	0.65	0.10
Land	1.040	23.49	12.57	7.15	7.18	7.58	8.52	9.51	11.54	6.72	8.04	5.52
Total $\mathbf{w^a F}^i$		**22.06**	**12.10**	**5.99**	**6.88**	**7.64**	**7.36**	**8.41**	**10.59**	**5.96**	**7.84**	**4.03**

Sources: For the sources of the $\breve{\mathbf{A}}$ matrix, trade flows and factor prices, please see the text.

Notes: Factor flows are in the measure indicated. Factor prices are for the period 1854-1857.

Table III: Robustness Checks for the Test of the Heckscher-Ohlin Theorem (Net Factor Trade in millions of ryō)

	1865	1867	1868	1869	1870	1871	1872	1873	1874	1875	1876
Panel A: Adjusting for Trade Imbalances											
$\left(\frac{\boldsymbol{pX}}{\boldsymbol{pM}}\right)^i$	*	0.77	*	0.67	0.47	0.95	0.76	0.81	0.90	0.73	*
Skilled male	-0.24	-0.24	-0.17	-0.17	-0.27	-0.42	-0.41	-0.37	-0.43	-0.43	-0.50
Unskilled male	-0.92	-0.36	-0.61	-0.29	-0.29	-0.54	-0.62	-0.71	-0.47	-0.69	-1.10
Female	-0.13	0.01	-0.03	0.01	0.02	0.04	0.02	-0.00	0.10	0.02	0.00
Capital	-0.15	-0.13	-0.34	-0.21	-0.32	-0.32	-0.44	-0.18	-0.15	0.22	0.10
Land	23.49	9.44	7.15	4.71	3.28	8.04	7.07	9.25	5.97	5.70	5.52
Total $\boldsymbol{w}^a\widetilde{\boldsymbol{F}}^i$	**22.06**	**8.72**	**5.99**	**4.04**	**2.43**	**6.80**	**5.62**	**8.00**	**5.02**	**4.81**	**4.03**
Panel B: Adjusting for Differences in the Quality of Land											
Skilled male	-0.24	-0.21	-0.17	-0.14	-0.23	-0.42	-0.39	-0.36	-0.42	-0.40	-0.50
Unskilled male	-0.92	-0.28	-0.61	-0.14	0.12	-0.51	-0.53	-0.63	-0.42	-0.56	-1.10
Female	-0.13	0.05	-0.03	0.07	0.18	0.05	0.07	0.04	0.13	0.10	0.00
Capital	-0.15	-0.03	-0.34	-0.09	-0.01	-0.31	-0.30	-0.04	-0.11	0.51	-0.00
Land	1.58	2.01	1.30	2.45	3.27	2.69	3.06	2.97	2.26	3.25	2.21
Total $\mathbf{w}^{\mathbf{a}}\ \mathbf{F}^{\mathbf{i}}$	**0.15**	**1.53**	**0.14**	**2.14**	**3.33**	**1.50**	**1.91**	**1.98**	**1.45**	**2.91**	**0.62**
Panel C: Adjusting for Trade Imbalances and Differences in the Quality of Land											
Skilled male	-0.24	-0.24	-0.17	-0.17	-0.27	-0.42	-0.41	-0.37	-0.43	-0.43	-0.50
Unskilled male	-0.92	-0.36	-0.61	-0.29	-0.29	-0.54	-0.62	-0.71	-0.47	-0.69	-1.10
Female	-0.13	0.01	-0.03	0.01	0.02	0.04	0.02	0.00	0.10	0.02	0.00
Capital	-0.15	-0.13	-0.34	-0.22	-0.32	-0.35	-0.47	-0.21	-0.19	0.11	-0.00
Land	1.58	1.46	1.30	1.52	1.28	2.52	2.18	2.28	1.96	2.18	2.21
Total $\boldsymbol{w}^a\widetilde{\boldsymbol{F}}^i$	**0.15**	**0.74**	**0.14**	**0.85**	**0.42**	**1.24**	**0.69**	**1.00**	**0.96**	**1.19**	**0.62**

Notes: Years with a * in the first row were years with a positive balance of trade.
Source: For a discussion of the procedures used to adjust for trade imbalances and differences in the quality of land, please see the text.

Data Appendix for Daniel M. Bernhofen and John C. Brown, "Testing the General Validity of the Heckscher-Ohlin Theorem"

The data appendix provides information on the sources for the trading vector **T**, the $\mathbf{A^J}$ and $\mathbf{A^{ROW}}$ matrices and the the vector of autarky prices $\mathbf{w^a}$. A concluding section discusses the procedure to adjust land inputs into woolens for differences in the quality of land.

*Trade vector **T***

Western consular reports from 1865 and 1867 provide the trade data for the years prior to the establishment of the customs service under the Meiji government.[27] Along with the imports recorded in the tables, imports of ships noted elsewhere in the consular reports were also included. For the period 1868-1876, Shuzeikyoku (1893) provides the data from the official Meiji customs reports. The consular reports for Belgium, Germany, the United States and Great Britain, the reports of several trade delegations and local newspapers provide copious detail on the characteristics of these imports, including weight, dimensions and the source country. [28] The trade data for 1865-1867 often express imports of cotton and woolen cloth in terms of pieces rather than yards. The reports noted above allow conversion of this information on imports into square yards.[29] Supplementary information from these sources was also used to fill in some of the detail on imports of woolens and iron products that was missing from the early customs

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[27] See Great Britain**.** "Commercial Reports by Her Majesty's Consuls in Japan" for 1865 and 1867. A fire in the largest treaty port of Kanagawa (near Yokohama) destroyed the trade records for 1866. Additional data were provided by the consular reports found in Belgium. Ministère des affaires étrangères and Prussia. Ministerium für Handel Gewerbe und Öffentliche Arbeiten. The total imports included the purchase of ships.

[28] See these consular reports Great Britain**.** "Commercial Reports by Her Majesty's Consuls in Japan", Belgium. Ministère des affaires étrangères, Prussia. Ministerium für Handel Gewerbe und Öffentliche Arbeiten, and United States. Bureau of Foreign Commerce. The reports of the trade delegations from Switzerland, Prussia and Austria-Hungary offered valuable detail for the 1860s. See Jacob (1861, Switzerland. Eidgenössisches Handels- und Zolldepartment and Brennwald (1865), and Scherzer (1872). All of these sources include the kinds of information that would enable potential exporters to Japan to meet Japanese demands.

[29] Additional valuable sources on the dimensions of imported cotton cloths are Wagner (1862), Mitchell (1869), and United States Tariff Board (1912).

reports. The trade statistics include seventeen categories of cotton cloth and fifteen categories of woolen cloth. To facilitate matching cloth imports with information on the technologies used to produce them, the cotton cloths were grouped into five categories by weight and fineness of yarn and the woolen cloths were grouped into eleven categories by weight, type of yarn (worsted, woolen or mixed worsted/woolen and cotton) and country of origin.[30]

Matrix of unit input requirements for exports and imports $\breve{A}$

The elements of the $\breve{\mathbf{A}}$ matrix describe the production technologies in use in Japan for producing exports (the submatrix $\mathbf{A^J}$) and the technologies used in the main source country for imports (the submatrix $\mathbf{A^{ROW}}$). The methodology used in the construction of the $\breve{\mathbf{A}}$ matrix required identification of the most important input-output relationships and then the quantities of labor, capital and land that contribute to the value-added at each stage of production. Fortunately, production technologies of the nineteenth-century allow for the mapping of the most important input-output relationships and the rich sources available permit a detailed accounting of the resources used at each stage of production.

An examination of both Japanese and rest of the world technologies suggests that five fundamental resources can be employed to describe technologies: three categories of labor (skilled male labor, unskilled male labor and female labor), capital, and land.[31] The choice of three types of labor reflects the strong emphasis in accounts of both the east and west of a strong division of labor by sex and the importance of highly-skilled craft workers as a distinctive feature of cross-national differences in nineteenth-century technologies (see Rosenberg [1969]). Sources generally refer to the gender of workers. The distinction between skilled and unskilled workers was made on the basis of occupational titles (coolies or laborers were always unskilled

[30] Additional details on the classifications are available from the authors.
[31] In the circumstances where the sources reference the employment of boys, they are assigned to female labor.

workers) and where necessary, on wages paid. Virtually all sources provide wages for unskilled workers, which allowed identification of skilled workers. Labor was measured in terms of days of work.[32]

The measurement of capital was based on the annual user cost of capital as defined in OECD (2009, p. 65): $c_o=P^o(r+\delta)$, where c_o is the capital cost of production, P^o is the price of the capital (including the construction cost of buildings as well as machinery or tools), r is the relevant interest rate, and δ is the rate of depreciation. In the **Ă** matrix, the amount of capital used in production (c_o) is expressed per unit of output. Virtually all of the Japanese sources provide $P^o\delta$, and most sources for western industries also provide an estimate of r. Where this information is lacking, a depreciation rate of 10 percent is assumed for wooden capital such as looms and tools and an interest rate of 12 percent is assumed for Japan (See Saitō and Settsu [2006]). Depreciation rates and interest rates for Japan's trading partners are from the sources for individual countries. Capital is measured in terms of gold ryō of 1854-1857.[33]

East Asian agricultural land was either paddy land (irrigated fields suitable for flooding to produce rice) or "dryfields", which was comparable in use to cropland in the west. Initially, all land (east and west) was assumed to be dryfields. It was measured in terms of *tan*, an areal measure equivalent to one-tenth of a hectare or one-quarter of an acre.

The construction of the **Ă** matrix took account of the most important intermediate goods. For some products such as woolen or cotton goods, imported raw materials played an important role as well. Most countries involved (including Japan) lack the comprehensive national

[32] The days of labor were almost always reported in Japanese sources and many of the main sources for western technologies, including United States. Department of Labor and Wright (1892) and United States. Bureau of Labor and Wright (1891). In the absence of this information, the work year was assumed to have about 300 days for Europe and Japan (see Huberman and Minns [2007]).

[33] The gold ryō was the gold-backed currency of pre-1871 Japan. It was replaced by the yen in 1871 at a ratio of one to one. The index of non-tradeable goods found in Shinbo (1978, Table 5-10) was used to convert values in yen or other currencies into gold ryō of 1854-1857.

manufacturing or agricultural censuses for the nineteenth century of sufficient detail that could be used to construct the **Ǎ** matrix. Even if census data were available, it may not always be sufficiently detailed to provide a close match with traded goods. Fortunately, abundant sources are available to find the main resource requirements. They include comprehensive national studies of production conditions (either as large-scale surveys or parliamentary enquiries), detailed industry studies by competitor countries of production conditions among the main exporters of a good to world markets, national or state-level surveys similar to manufacturing censuses, contemporary and historical monographs, and government reports. Appendix Tables AI and AII list the main products in the $\mathbf{A^J}$ and $\mathbf{A^{ROW}}$ matrices, the main type of sources used and the most important references. All told, the $\mathbf{A^J}$ matrix includes 24 products that accounted for about 97 percent of the value of Japan's exports. The $\mathbf{A^{ROW}}$ matrix allows for the calculation of the input requirements for 32 kinds of cotton and woolen imports and about 17 other kinds of imports, which in total accounted for over 80 percent of Japan's imports.

Virtually all Japanese exports during the early trade period were produced in rural areas with vertically dis-integrated production units based on the farm. For that reason, the most important of the sources referenced in Table AI is the Nōji Chōsa (See Chō, Shōda and Ōhashi [1979]), an ambitious prefecture-by-prefecture survey by the Meiji government in 1888 to develop a statistical portrait of rural production conditions that is unmatched by any comparable historical source.[34] The construction of the relevant columns of the $\mathbf{A^J}$ matrix used the data from the prefectures that specialized in the respective export products, including silk products and tea.

[34] Although compiled in the 1880s, the data are reflective of conditions a decade earlier. The main change in Japanese agriculture after 1868 was the modernization of rice production known as the *Meiji Nōhō*, which was a regime of double-cropping that included planting faster-maturing strains of rice, plowing rice paddies with horses and applying more fertilizer. Francks (1984, pp. 55-63) reviews the literature and finds that the most significant diffusion of these methods took place well after the 1880s.[34]

The data in this source are by task, which allows a careful assessment of input requirements for industries such as silk, for which several stages of production were required.[35]

Of necessity, the imports listed in Table AII involve a wide range of countries and potential sources of data. The most valuable sources for British metals and textiles were the series of studies carried out by American consuls and the United States Department of Labor, which attempted to identify the sources of competitive success of British and continental producers. The report on German exhibitors at the 1867 Paris Exposition and French and German parliamentary inquests, which were carried out in response to stiff foreign competition during the 1860s and 1870s, provide valuable information on their respective woolen and worsted industries. Monographs published on various aspects of the industries of both countries supplemented this material. The monumental studies by John Lossing Buck of Chinese agriculture provide enough detail to allow an assessment of resource needs for farms that marketed a substantial share of their rice, soybean, and cotton crops.

Figure AI illustrates the methodology used to construct the **Ă** matrix. It documents the amount of land, labor, and capital and intermediate goods required for each of the main activities associated with producing one square yard of dyed shirtings, a type of medium-weight finished cloth imported into Japan. Since the British cotton textile industry was vertically disintegrated, data collection was required for each separate stage of production: spinning, weaving, and dyeing. In addition, the amount of intermediate inputs at each successive stage of production was required. For example, the coal requirements and raw cotton requirements for one pound of

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[35] Silk production involved mulberry leaves, silkworm eggs, cocoons and reeling silk. Each of these stages of production would be carried out by a separate household, which would then be linked by active markets in the three intermediate products. The prefectures used for the analysis of silk production coefficients accounted for one-half of silkworm egg production, one-fourth of cocoons and one-fifth of raw silk production in 1874 (see Le Gendre [1878, Appendix Table]). The prefectures used for the analysis of tea exports accounted for about 20 percent of exports in 1873/74 (see Anonymous [1875]).

28/36s yarn are well-documented in the literature, including the 12 percent waste of the American cotton that was used in spinning 28/36s yarn and the need for about four pounds of coal per pound of yarn. Finally, the resources required for the main intermediate goods were also identified. In the case of dyed cloth, they include three inputs (cotton, indigo dye, and timber) that were imported into Britain. American cotton was used for the medium and higher count yarns that were used in this cloth. Indigo dye was produced in India with two stages of production: raising the indigo leaves on farms and then processing them into indigo balls that were then marketed worldwide. Swedish timber was a key import for the mining of coal. In a small number of cases, resource requirements for some processes (such as capital for dyeing) were not available. In this example, of a total of about 0.136 days of labor were required to produce a square yard of dyed shirtings, Of this total, the labor required to grow cotton accounted for 43 percent, the factory labor required to spin yarn, weave cloth and then dye it accounted for 32 percent, and the indigo dye, coal and timber accounted for the remaining 25 percent. Based upon the data from cotton textiles, well over 95 percent of the costs of production were captured by this approach to identifying resource costs.

Vector of autarky factor prices $\boldsymbol{w^a}$

Autarky prices for capital, labor and land are expressed in terms of gold ryō.[36] Capital is treated as the numéraire priced at one gold ryō. Since wages did vary across Japan, two issues matter for determining the appropriate autarky price of labor: the locus of production of tradable goods (rural versus urban) and potential differences in wages in eastern (Kantō) versus western Japan (Kinai). Virtually all production of tradable goods took place in the rural locations or small towns, so that wages outside of the major urban centers of Osaka, Kyoto and Edo (Tokyo) are

[36] All factor prices from the western part of the country, which included the Kinai region in the area of Osaka and Kyoto, used a silver-based currency (the silver *momme).* The monthly exchange rates of the *momme* with the ryō found in Miyamoto and Ōsaka Daigaku Kinsei Bukkashi Kenkyūkai (1963) are used to convert these values to ryō.

appropriate. The research of Saito and other historians amply documents autarky wage rates (see Saitō [1973, 1991, 1998a, 1998b, and 2005]).

Appendix Table AIII presents Saito's estimates of the daily wage paid for female agricultural workers in both the Kinai (western) and the Kantō (eastern) regions and his estimates of the pay of male agricultural workers in the Kinai. Wage rates for male farm workers in the Kinai region were 0.027 in the mid-1850s at the close of the autarky period. Daily wage rates for comparable low- or semi-skilled workers in the Kantō region available from other sources were in the range 0.027-0.031. Finally, evidence is available on the wages paid to skilled workers in the Kantō region in the mid-1850s and for the Osaka region in the mid-1840s. In the east, highly-skilled workers earned 0.048 to 0.050 ryō per day in the mid-1850s. Skilled workers in the construction trades and workers with middle-level skills at a soya sauce factory would have earned closer to 0.041-0.044 ryō. In the west, the range was up to about 0.053 for a skilled cotton scutcher in rural areas in the early 1840s. Since Japan was always a net exporter of male skilled and unskilled labor and often an exporter of female labor, the maximum of the values in columns 2 and 3 was chosen as the autarky prices for the hypothesis test. This approach biased the test results towards rejection of the hypothesis.

Land quality and prices varied across Japan. The most land-intensive imports over the early trade period were cotton and woolen textiles. The most land-intensive exports were tea and silk, although they generally used marginal land that did not compete with crops usually grown on dryfields such as grains and beans. Data on land values and rents during the late autarky period are most readily available for the productive heartland of autarky Japan, the Kinai.[37] The

[37] See Hensan-iinkai (1967, Tables 28 and 65) and Takeyasu (1968, Table I-27) for the records of several villages in the vicinity of present-day Osaka. Japanese tax authorities classified all plots of land into four categories: very low quality, low quality, medium or standard quality and high quality. Land was also classified as paddy land or dryfield land.

data include information on the proportion of paddy land and the quality of the land according to tax assessments. Rents are expressed either in terms of cash or rice. Hedonic regressions carried out on these data suggest that rents in the Kinai ranged between 1.34 to 1.82 ryō per tan for standard quality dryfields ca. 1854. The rice equivalent yields of several of the villages were about 1.74 to 2 koku, which suggests that this land was about one-quarter to almost one-half more productive than the average rice productivity of 1.36 koku for all land in Japan in 1874 (see Le Gendre [1878, Appendix Table].[38] Adjusting the rents from the Kinai downwards to reflect an average for all of Japan results in a range of 1.04 (=1.36/1.74*1.34) to 1.24 ryō. For the Heckscher-Ohlin test, the rent was set at the minimum of this range (1.04 ryō), since Japan was consistently a net importer of land.

Adjustments for differences in the quality of land

Pastoral agriculture made use of land of lower quality and productivity than land that was suited for raising crops. Since autarky prices in Japan are measured in terms of tan of dryfields (cropland), the failure to adjust the amount of land used to produce wool to reflect quality differentials would lead to an overstatement of Japan's imports of the factor land. As column (2) of Appendix Table AIV indicates, the amount of land required per sheep varied significantly across suppliers of wool. Germany's sheep-raising areas used somewhat less land per sheep than France and Great Britain, perhaps because German agriculture was relatively efficient in comparison with the other two countries. French methods of raising sheep were intensive in the use of cropland. As would be expected, countries specializing in pastoral agriculture such as Argentina or Australia used land-intensive methods. To arrive at a dryfield equivalent for the land used in raising sheep, the following expression was used:

[38] A koku was the standard measure for all grains and was about 5.1 bushels.

$$(1)\ Acres/sheep^{dryfield} = \sigma\frac{Acres}{Sheep} + (1-\sigma)\frac{Acres}{Sheep} * \frac{Rent^{Pasture}}{Rent^{Cropland}},$$

where σ is the share of the actual amount of acreage used per sheep that is cropland. The necessary data and sources for this calculation are reported in columns (3) through (5) of Table AIV. The rent for cropland in Great Britain (216 pence) was used in the right hand side of (1) to calculate the dryfield equivalent in Argentina and Australia, since Great Britain was the only one of the European countries practicing free trade in grains. Column (6) contains the resulting dryfield equivalent. Adjusting for land quality shaves off as much as 90 percent of the unit input coefficient for raising sheep in Argentina and up to 97 percent for raising sheep in Australia. These adjustments are applied to the land input coefficients for all wool production.

The adjustments accord reasonably well with what we know about the rapid changes in European patterns of wool consumption during the last third of the nineteenth century. Germany remained a net exporter of wool until the mid-1860s, when its domestic wool industry began a slow decline. Despite its appetite for wool from South Africa, Australia and New Zealand, British imports of wool only gradually increased over the nineteenth century. France’s domestic production of wool suffered the most dramatic decline.[39]

[39] Senkel (1901) offers a good overview of these issues.

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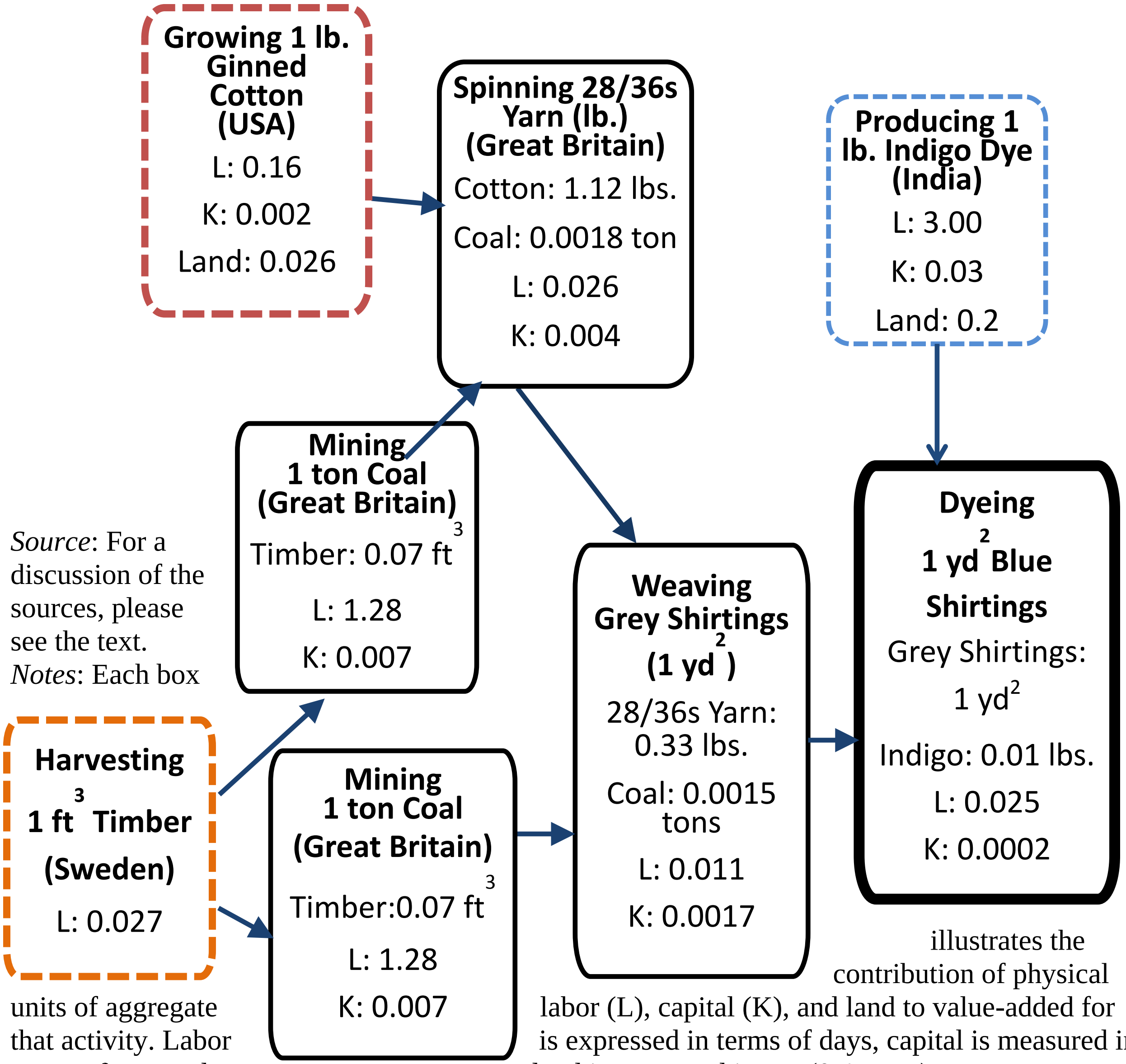
Figure AI: The Unit Factor Requirements for the Activities Necessary to Produce Blue Dyed Shirtings in Great Britain



Source: For a discussion of the sources, please see the text.
Notes: Each box illustrates the contribution of physical labor (L), capital (K), and land to value-added for units of aggregate that activity. Labor is expressed in terms of days, capital is measured in terms of ryō, and land is measured in *tan* (0.4 acres).

Table AI: Sources Used for Constructing the $\mathbf{A}^{\mathbf{J}}$ matrix

Product	Type of source	Main references
Raw Silk, Silkworm eggs, Cocoons, mulberry leaves (intermediate)	Survey of production conditions (Nōji Chōsa) and monographs	Chō, Shōda and Ōhashi (1979), Syrski (1872), Bavier (1874)
Tea	Survey of production conditions (Nōji Chōsa) and monographs	Chō, Shōda and Ōhashi (1979),Watson (1873), Gribble (1883)
Tobacco, Cotton, Rice, Soy	Survey of production conditions (Nōji Chōsa)	Chō, Shōda and Ōhashi (1979)
Copper	Accounts of western observers and monograph	Coignet and Ishikawa (1957), Lyman (1879),Japan Rinji Hakurankai Jimukyoku (Chicago Exposition 1893) (1975),Takeda (1987)
Coal	Government reports	Nishi Nihon Bunka Kyōkai (1982)
Maritime products (Iriko, Awabi, Cuttlefish, Seaweed)	Government reports and reports of competitors	Anonymous (1893),Smith and Smith (1905),Hokusuikyokai (1935), Habara (1940),
Camphor	Monograph	Greathouse (1887)
Mushrooms	Monograph	Department of Agriculture and Commerce Bureau of Forestry (1904)
Vegetable Wax	Monograph	Gribble (1874)
Charcoal (intermediate)	Monograph	Dupont (1879),Mimura (1915),Tanaka (1984)
Fish fertilizer (intermediate)	Monograph	Murao (1984),Nakanishi (1998)
Wood (intermediate)	Monograph	Hokusuikyokai (1935)

Table AII: Sources used for Constructing the $\mathbf{A}^{\mathbf{ROW}}$ matrix

Product	Country of Origin	Type of Source	Selected references
Cotton yarn	Great Britain	Competitor country report	Manchester Chamber of Commerce (Manchester England) (1888)
Cotton cloth	Great Britain	Competitor country report, monograph	Shaw (1882),United States. Department of Labor and Wright (1892)
Woolen and worsted cloth	Great Britain	Large-scale surveys, Competitor country report, monograph	Rivers Pollution Commission (1868) (1874), United States. Department of Labor. and Wright (1892),Clark (1908)
Woolen and worsted cloth	Germany	Parliamentary enquiries, large-scale surveys	Mährlen (1861), Editeur de la Commission Imperiale (1867),Germany. Enquete-kommission für die Baumwollen- und Leinen-industrie (1878),Quandt (1895)
Worsted cloth	France	Parliamentary enquiries, monograph	Turgan (1860),France. Conseil supérieur de l'agriculture du commerce et de l'industrie. (1862),Daumas (2004)
Raw Cotton, Rice and Soybean	China	Monograph, large-scale survey	Buck (1926),Buck (1937), Buck, Jinling da xue, Nong xue yuan, and Institute of Pacific Relations. (1937)
Sugar (Brown and White)	Formosa	Monograph	Davidson (1903)
Indigo	India	Monograph	Anonymous (1858)
Iron and Steel	Great Britain	Competitor country report, monograph	Bevan (1876),Bell (1886),United States. Bureau of Labor and Wright (1891),Schwarz (1902)
Lead	Great Britain	Monograph	Spargo (1865)
Kerosene	United States	Monograph	Gesner and Gesner (1865)
Weapons and ammunition	Great Britain	Monograph	Goodman (1866),Williams (2005)
Coal (intermediate)	Great Britain	Competitor country report	Schoenhof (1886)
Raw Cotton (intermediate)	United States and India	Monograph, government reports	Medlicott (1862),Barber (1866),Baden-Powell (1868)
Timber (intermediate)	Sweden	Competitor country report	United States. Department of Commerce (1921)
Wool (intermediate)	Argentina, Australia, France, Great	Competitor country report, monograph	Kenworthy (1865), Griffin (1890),Gibson (1893)

Britain, Germany

Table AIII: Autarky Factor Prices (in gold ryō)

Factor	Eastern Japan (Kantō)	Western Japan (Kinai)	Hypothesis Test
Female Labor (daily)	0.018 (1856-60)	0.019 (1851-55)	0.019
Male Unskilled Labor (daily)	0.027-0.031 (mid-1850s)	0.027 (1854/1857)	0.031
Male Skilled Labor (daily)	0.036-0.049 (1847) 0.048-0.050 (1856)	0.049-0.053 (1843)	0.053
Land in a dryfield (annual per tan)	1.34-1.82 (mid-1850s)		1.04

Notes: The ranges refer to values found in historical sources. The value in the final column is the value adopted for the hypothesis test.

Sources: The wages for female labor and for unskilled male labor in the Kinai are from Saitō (1973).The wages for males unskilled labor in eastern Japan are from Suzuki (1990) for an unskilled lad (*wakamono*) at a soy brewery north of Tokyo (including a 1 sho of rice each day), a water-wheel attendant at a charcoal blast furnace in the Iwate prefecture (see Kojo [1992, pp. 201-202]) and the daily earnings of a young male belt weaver in the Ashikagi district northeast of Tokyo (see Waseda Daigaku Keizaishi Gakkai [1960, p. 257]). Wages for skilled workers in eastern Japan for 1847 are for a range from a joiner up to a plasterer and are from Tokorozawa Shishi Hensan, Iinkai (1979). . For 1856, they are the average wage of the three most skilled workers (tōji and kashira) found in the Suzuki (1990) study of a soya sauce manufacturer and the wage earned by the "key worker" of a charcoal blast furnace provided by Tojo (1992, pp. 201-202). For western Japan in 1843, the range is for a scutcher (cotton processer) and carpenters in four villages near Osaka from Izumiotsu-shi (1995, pp.563-571). The land rents are from hedonic rent analysis of rents in several villages in the vicinity of Osaka ca. 1854, which are published in Hensan-iinkai (1967, Tables 28 and 65) and Takeyasu (1968, Table I-27). They have been adjusted downwards to reflect the average productivity of crop land in all of Japan.

Table AIV: Assessing the Relative Quality of Land in Wool Importing and Wool Exporting Countries ca. 1885

	Acres per Sheep (2)	Share of Crop Land (3)	Pence per Acre of Cropland (4)	Pence per Acre of Pasture (5)	Acres per Sheep Dryfield (6)
France	0.57	100	230	NA	0.57
Germany (1865)	0.22	85	84	16	0.19
Great Britain	0.60	33	216	90	0.45
Argentina	0.57	0		23	0.06
Australia	2.50	0		5	0.05

Notes: The acres per sheep in column (2) include both cropland and pasture. For an explanation of the calculation of a dryfield equivalent, please see the text.

Sources: For columns (2) and (3): Sanson (1875, p. 124) adjusted for a full year for France; Sinclair (1898, pp. 195-203) for Great Britain and Mendelson (1904, pp. 130-131) for Germany. Gibson (1893. p. 102) provides the acres per sheep for "second-class land" in Argentina and Griffin (1890, pp. 252-256) offers an average for Victoria and New South Wales. For column (4): rents on British farmland are fromTurner, Beckett and Afton (1997, Fig. 9.8). Rents on French Farmland are from France. Ministère de l'agriculture (1887, pp. 266-269) for several départements that specialized in raising sheep. Rents on German farmland are for Silesia in 1865 from the assessments of land for taxation discussed in Meitzen, Grossman and Prussia (1868, p. 211) and may not be strictly comparable with the rents for the 1880s. For column (5): average of range presented in United States. Tariff Board (1912, p. 450) for British sheep farms. For Germany, the source is Meitzen, Grossman and Prussia (1868, p. 296). For Argentina, the rents are from Gibson (1893, p. 105) and for Australia, the rents are from Griffin (1890, p.252) for leased sheep walks.