A Direct Test of the Theory of Comparative Advantage: The Case of Japan

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We exploit Japan's sudden and complete opening up to international trade in the 1860s to test the empirical validity of one of the oldest and most fundamental propositions in economics: the theory of comparative advantage. Historical evidence supports the assertion that the characteristics of the Japanese economy at the time were compatible with the key assumptions of the neoclassical trade model. Using detailed product-specific data on autarky prices and trade flows, we find that the autarky price value of Japan's trade is negative for each year of the period 1868–75. This confirms the prediction of the theory.

I. Introduction

This paper provides a direct test of the theory of comparative advantage in its autarky price formulation. It exploits Japan's dramatic nineteenth-century move from a state of near complete isolation to one that was fully exposed to the forces of international competition and argues that the case of Japan provides a natural experiment to explore the empirical validity of the theory.

We test the correlation version of the law of comparative advantage

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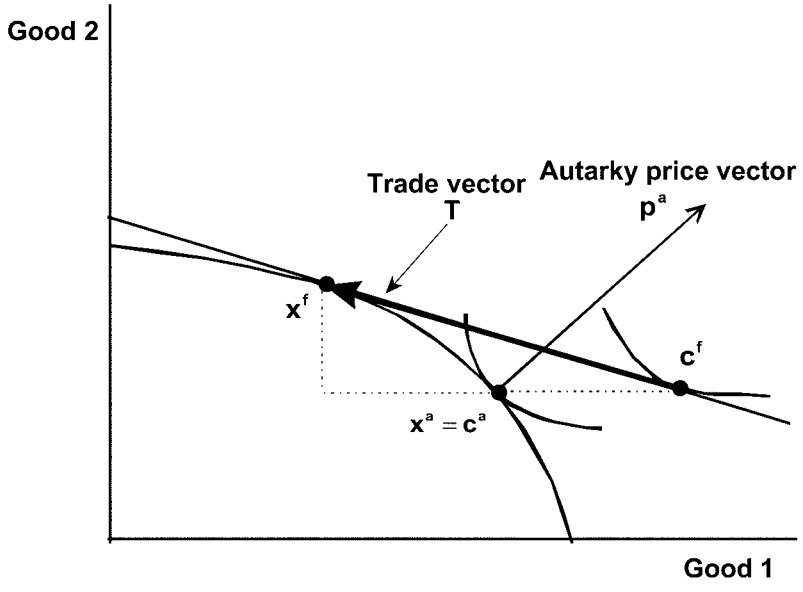

FIG. 1.—The law of comparative advantage with two goods

developed by Deardorff (1980). It asserts that an economy's net export vector evaluated at autarky prices is negative.[1] In a world with just two goods (see fig. 1), this is equivalent to the proposition that the economy will export the good with the lower relative opportunity cost.[2] If one generalizes to the case of more than two goods, it is not possible to predict the import or export patterns of individual commodities. However, the correlation version of the law of comparative advantage is robust in higher dimensions. The theory asserts that, *on average*, a country will import what is dear and export what is cheap, with the valuation taking place at autarky prices.

An empirical test of this proposition requires only data on a country's autarky prices and its international trade flows. Autarky prices incorporate all relevant information about a country's intrinsic supply and demand conditions.[3] The trading vector contains all the necessary in-

[1] Independently of Deardorff, Dixit and Norman (1980, pp. 94–96) derived the same result. However, their analysis was not formulated and developed as thoroughly as Deardorff's.

[2] While under autarky the economy's production point coincides with its consumption point ($\mathbf{x}^a = \mathbf{c}^a$), international trade allows the production point $\mathbf{x}^f$ to be distinct from the consumption point $\mathbf{c}^f$. In fig. 1, the economy has a comparative advantage in good 2 (or the slope of the production possibility frontier at $\mathbf{x}^f$ is flatter than at $\mathbf{x}^a$). This implies that the economy's trade vector evaluated at autarky prices is negative, or $\mathbf{p}^a\mathbf{T} < 0$.

[3] The insight that prices contain the relevant information about underlying economic fundamentals goes back to the pioneering work of Hayek (1945).

formation about its trading partners. Consequently, the value of a country's trade at autarky prices is a sufficient basis for a comparative advantage proposition.[4]

While several previous studies, most notably Huber (1971) but also Williamson (1999), have drawn on the Japanese case, their primary focus was to make inferences about the welfare and distributional implications of Japan's opening to trade. In order to achieve this, they focused on a narrow range of commodities and prices. With its test of the fundamental proposition of comparative advantage, this study breaks new ground. Guided by the data requirements of the theory, we have constructed a comprehensive product-specific data set on autarky commodity prices and trade flows. It draws on a rich collection of autarky price data from a variety of historical sources.

In contrast to the often complex and sophisticated product characteristics of goods traded internationally today, the commodities that initially entered into Japanese trade after it opened up were predominantly agricultural or simple manufactured goods. They can be reasonably characterized as homogeneous goods. Since the historical evidence suggests that these goods were priced under fairly competitive market conditions, the observed autarky prices appear to be excellent measures of Japan's relative opportunity costs at the time. The time period selected for the natural experiment begins with the final years of Japan's complete economic and political isolation (1851–53). Japan actually opened its markets to trade in mid-1859, and the analysis employs trade data from about one decade later (1868–75) when Japan's external trading regime could be reasonably described as "free trade" and trade data of adequate quality and detail are available. Our finding that Japan's autarky price value of trade is negative for each single year of the sample period 1868–75 provides strong empirical support for the prediction of the theory of comparative advantage.

The paper is organized as follows. Section II introduces the theoretical framework. Section III discusses the case of Japan and provides evidence for the claim that Japan's entrance into world commerce can be perceived as a "natural experiment" that offers an opportunity to test the theory. Section IV specifies the empirical framework, describes the data sources, discusses measurement issues, and reports the empirical findings. Concluding remarks are contained in Section V.

[4] The unavailability of autarky prices has been the key obstacle for conducting a direct test of the theory of comparative advantage. Hence, the empirical literature in international trade has almost exclusively focused on models that point to different measurable sources of comparative advantage. Deardorff (1984), Leamer and Levinsohn (1995), Davis and Weinstein (2003), and Harrigan (2003) provide excellent surveys of this literature.

II. Theory

A. *Autarky versus Free Trade: What Does It Mean?*

The law of comparative advantage involves a comparison of autarky and free trade. The static trade model implicitly assumes that the economy's production possibilities are the same under both regimes. Empirically, it is possible that Japan's production possibilities did change during the country's transition from autarky to free trade. Following Helpman and Krugman (1985, p. 39), we view the comparison as one between two potential histories:

> To the extent that a static trade model is used as a proxy for a dynamic world … the comparison of autarky with free trade should be understood as a comparison between two alternative histories, not as a change that takes place over time. … The question is not where you are after trade compared with where you were before, but where you are after trade compared with where you *would have been* without trade.

When this insight is applied to this study, investigating Japan's pattern of trade should involve a comparison between the observed free-trade regime (1870s) and an autarky regime at the same time period (1870s) that would have prevailed had Japan not opened its doors to world markets. Consequently, we shall focus on three states in the history of the Japanese economy. Regime A is the autarky regime that prevailed through 1858 (period 1), regime B is the hypothetical autarky regime that would have prevailed during the early 1870s had Japan remained closed (period 2 of the comparison), and regime C is the actual free-trade regime of the early 1870s used in the empirical analysis (also period 2).

Consider a competitive economy with n goods, and denote by $\mathbf{p}_t^i$ the n-vector of equilibrium goods prices, $\mathbf{x}_t^i$ the n-vector of equilibrium production outputs, and $\mathbf{c}_t^i$ the n-vector of equilibrium consumption levels. The superscript a is used to denote a variable under autarky, and the superscript f denotes a variable under free trade (i.e., $i = a, f$). The subscript t pertains to one of the two time periods (i.e., $t = 1, 2$). In each period, production points are constrained to lie in a technologically feasible production set F_t ($t = 1, 2$). While the equilibrium prices under autarky, $\mathbf{p}_t^a$ ($t = 1, 2$), are determined solely by domestic supply and demand conditions, the equilibrium price vector under free trade,

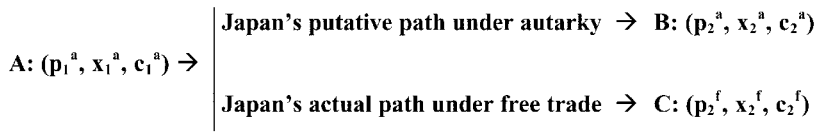

FIG. 2.—Two comparative histories of an economy

$\mathbf{p}_2^f$, is exogenous to the domestic economy. The subsequent analysis pertains to three competitive equilibria:

$$\text{(autarky) regime A: } (\mathbf{p}_1^a, \mathbf{x}_1^a, \mathbf{c}_1^a),\ \mathbf{x}_1^a \in F_1,$$

$$\text{(autarky) regime B: } (\mathbf{p}_2^a, \mathbf{x}_2^a, \mathbf{c}_2^a),\ \mathbf{x}_2^a \in F_2,$$

$$\text{(free-trade) regime C: } (\mathbf{p}_2^f, \mathbf{x}_2^f, \mathbf{c}_2^f),\ \mathbf{x}_2^f \in F_2.$$

The discussion above implies that the law of comparative advantage involves a comparison of Japan's historical path under free trade with its historical path if it had continued to operate under autarky (i.e., regime C vs. regime B). The absence of information on the unobservable autarky regime B will require an assessment of the conditions under which what is observed in autarky under regime A permits inferences about the validity of the law of comparative advantage. The assessment will draw on the historical evidence available on the Japanese economy of the 1850s and the path taken during the early years of the open-trade regime. The different historical paths are illustrated in figure 2.

B. An Identification Condition

The model is based on three key assumptions.[5] First, it assumes that competitive producers maximize the value of production on a production possibility set F_t,

$$\mathbf{p}_t^i \mathbf{x}_t^i \geq \mathbf{p}_t^i \mathbf{x}_t \quad \text{for all } \mathbf{x}_t \in F_t \ (i = a, f;\ t = 1, 2). \tag{1}$$

Second, we assume that aggregate consumer preferences in period 2 are in accord with the weak axiom of revealed preference, that is,

$$\mathbf{p}_2^f \mathbf{c}_2^f \geq \mathbf{p}_2^f \mathbf{c}_2^a \Rightarrow \mathbf{p}_2^a \mathbf{c}_2^f > \mathbf{p}_2^a \mathbf{c}_2^a, \tag{2}$$

meaning that if $\mathbf{c}_2^f$ was preferred to $\mathbf{c}_2^a$ at $\mathbf{p}_2^f$, then $\mathbf{c}_2^f$ must not have been

[5] Our presentation of the theory follows the condensed formulation by Deardorff (1994). In an earlier paper (Deardorff 1980), he has shown that as long as export subsidies are ruled out, the theory is also valid in the presence of nontraded goods, transportation costs, and production distortions.

affordable to the economy at $\mathbf{p}_2^a$.[6] Finally, we need to rule out any trade surplus, that is,

$$\mathbf{p}_2^f \mathbf{T} \leq 0, \tag{3}$$

where $\mathbf{T}$ denotes the net export vector, defined as $\mathbf{T} = \mathbf{x}_2^f - \mathbf{c}_2^f$.[7] Given these conditions, we can state the law of comparative advantage.

LEMMA. *Law of comparative advantage.*—The value of net exports in period 2, evaluated at the (unobserved) autarky prices in period 2, is negative: $\mathbf{p}_2^a \mathbf{T} < 0$.

Proof. Expressions (1) and (3) imply that $\mathbf{p}_2^f \mathbf{c}_2^f = \mathbf{p}_2^f \mathbf{x}_2^f \geq \mathbf{p}_2^f \mathbf{x}_2^a = \mathbf{p}_2^f \mathbf{c}_2^a$. From (1) and (2), we then obtain $\mathbf{p}_2^a \mathbf{c}_2^f > \mathbf{p}_2^a \mathbf{c}_2^a = \mathbf{p}_2^a \mathbf{x}_2^a \geq \mathbf{p}_2^a \mathbf{x}_2^f \Rightarrow \mathbf{p}_2^a \mathbf{T} < 0$.

Fundamentally, the law is a proposition about the sign of the weighted average of a country's vector of traded goods, where the weights equal the corresponding opportunity costs (prices) under autarky. The negative sign implies that, on average, goods with relatively high autarky prices will be imported and goods with relatively low autarky prices will be exported.[8]

Since the autarky price vector $\mathbf{p}_2^a$ is not observed, this lemma cannot be directly implemented empirically. However, since we observe the autarky price vector $\mathbf{p}_1^a$, we can investigate a sufficient condition for the validity of the proposition if we substitute the observed autarky price vector $\mathbf{p}_1^a$ for the unobserved price vector $\mathbf{p}_2^a$. Recognizing that the counterfactual autarky price vector $\mathbf{p}_2^a$ can be written as $\mathbf{p}_2^a = \mathbf{p}_1^a + \epsilon$, where ϵ denotes an error term, we obtain the following identification condition for the law of comparative advantage.

PROPOSITION. As long as $\epsilon \mathbf{T} \leq 0$, then $\mathbf{p}_1^a \mathbf{T} < 0$ is a sufficient condition for Japan's trade pattern to be consistent with the general law of comparative advantage, that is, $\mathbf{p}_1^a \mathbf{T} < 0 \Rightarrow \mathbf{p}_2^a \mathbf{T} < 0$.

The identification condition $\epsilon \mathbf{T} \leq 0$ states either that the correlation between changes in autarky prices under a (hypothetical) closed economy growth path and the trading vector would be zero (i.e., $\epsilon \mathbf{T} = 0$) or that autarky prices would have fallen, on average, in goods that the economy actually exported (i.e., $\epsilon \mathbf{T} < 0$). The identification condition rules out that Japan's "(hypothetical) closed economy growth" from period 1 to period 2 would have been, on average, biased toward its importables. Given production conditions in mid-nineteenth-century Ja-

[6] A sufficient condition for the weak axiom of revealed preference is the existence of a well-behaved social utility function for the economy. However, Shimomura and Wong (1998) have shown that the general law of comparative advantage can be derived under somewhat weaker conditions that do not require the presence of a social utility function.

[7] Hence, good i is exported if $\mathbf{T}_i > 0$ and imported if $\mathbf{T}_i < 0$.

[8] Drabicki and Takayama (1979) and Dixit and Norman (1980, pp. 95–96) provide examples that illustrate that, with more than two goods, opportunity costs do not predict trading patterns good by good.

pan and the obstacles in the economy to rapidly adopting new western technologies, it is unlikely that $\epsilon \mathbf{T} > 0$, and the identification condition would most likely hold.

III. Japan's Opening Up as a Natural Experiment

In his survey on the empirical literature of international trade, Deardorff (1984, p. 470) argued that tests of the theory of comparative advantage remain virtually impossible to carry out because "almost all countries have engaged in trade throughout history, so that there is no experience with autarky from which to draw data." Japan's economic history offers a remarkable exception. As a well-developed market economy, which experienced over two centuries of autarky, it generated a rich record of price data. Forced by the western powers to move abruptly to a free-trade trading regime in 1859, Japan offers a natural experiment uniquely suited to test the core proposition of the theory of comparative advantage.

Japan's policy of autarky (or seclusion) began formally in 1639 when all contact between the Japanese and outsiders, including trade, was forbidden. The only exception was a small amount of regulated trade with the Dutch and the Chinese conducted from a spit of land in the harbor of Nagasaki. This trade had dwindled to insignificance by the end of the eighteenth century (Meylan 1861, pp. 93, 142). In the last years of seclusion, imports per capita were about 0.6 cents, compared with 9 cents in China before it was forced to open up in the 1840s and 5.9 cents during the brief closing of trade in the United States in 1808–9 (see Hildreth 1855, p. 506; Tilley 1861, p. 99; Irwin 2001, table 1). A small amount of trade was conducted through the Ryukyu Islands.

Treaty negotiations following the visit of Commodore Matthew Perry and his fleet in 1853 delayed the opening up of Japan until July 1859. The trade treaties designated three (later five) ports for international trade and established a liberal regime that capped tariffs and export duties at low effective ad valorem rates.[9] By the mid-1860s, military intervention by the western powers had forced the shogun to abandon rearguard efforts to restrict trade (Mathias-Pauer and Pauer 1992, p. xvi).

The shift from autarky to free trade was rapid and complete. Figure 3 illustrates the steep increase in trade during the first quarter century

[9] Revisions to trade treaties in 1866 set specific tariffs and export taxes that averaged about 2.5–3.5 percent ad valorem (von Scherzer 1872, pp. 381–99). The treaties allowed Japan to continue a long-standing ban on the export of rice and copper ore and prohibit the import of opium.

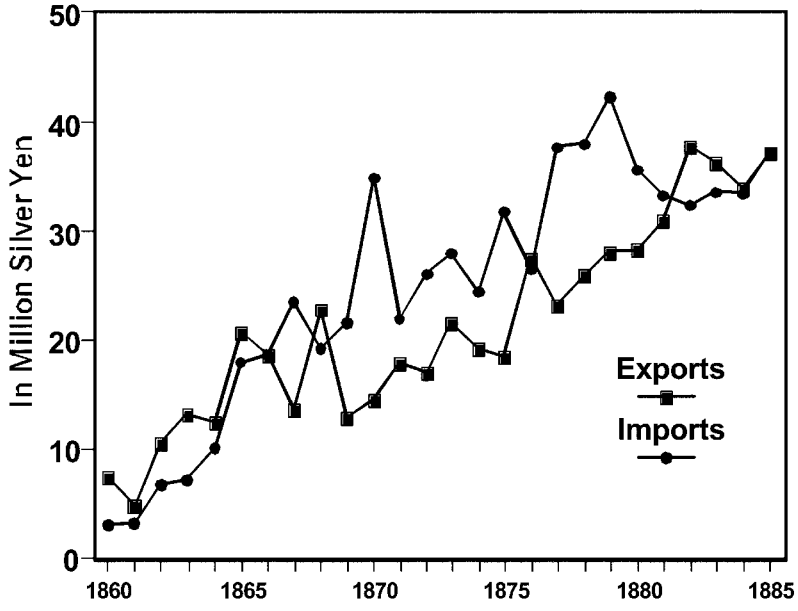

FIG. 3.—The development of Japan's external trade, 1860–85. Source: Sugiyama (1988, table 3-4).

after the opening up to trade.[10] Good communications, well-developed commercial networks, and national markets in many commodities prompted a substantial penetration of Japanese markets (Nakamura 1990, p. 94; Howe 1996, pp. 93–94). By 1873, Japan's imports per capita were 79 cents, or three times the level in China (see von Scherzer 1872, p. 256; Sugiyama 1988, p. 46).

Japan's move from autarky to free trade offers a suitable testing ground for the theory of comparative advantage if the economy and conditions of trade reasonably conform to four key assumptions of the neoclassical trade model. The first three assumptions ensure that the autarky prices and net export data used in the analysis convey the necessary information about domestic supply and demand conditions and opportunities for exchange with trading partners.

1. The vector of autarky prices reflected the outcome of competitive markets.
2. Japanese producers were price takers in international markets.

[10] The peak in exports in 1868 reflects exports of Japanese silk and silkworm eggs in response to the spread of a corpuscular disease in Italian and French silkworms. The peak in imports in 1870 reflects high imports of rice in response to the poor harvests of that year. Trade is valued in current Japanese (silver) yen.

3. Exports received no subsidies.

The final assumption ensures that the identification condition $\epsilon\mathbf{T} \leq 0$ holds, so that prices from the autarky period can be applied to the available data on trade.

4. Changes in production possibilities under a closed economy from the opening up to trade (1859) to the period in which the net export vector is analyzed (1868–75) would not have been biased toward importables.

Assumption 1 addresses competitive conditions in the economy under autarky and free trade. Economic historians have achieved a good understanding of the functioning of Japan's economy during the more than 250 years of Tokugawa rule that ended with the restoration of the emperor in 1868.[11] Initially, Japan had been organized as a feudal society. For the most part, manufacturing took place in small workshops of 30 workers or fewer (Takekoshi 1930, 3:270; Piper 1976, pp. 29–30). Agriculture was carried out on small farms. However, the feudal system initially included guild monopolies controlling the trade in many commodities and restrictions on the use of land and labor. Over the century ending in the early 1840s, the restrictions on trade were dismantled. By then, competitive conditions characterized virtually all output markets. The allocation of land and labor responded to movements in relative output prices.[12] Spectral analysis of the prices of bills of exchange provides quantitative support for the conclusions of historians. By the period 1822–43, regional integration and monetization had disrupted traditional feudal regulation of the economy (Yamamura and Duffy 1971, p. 422). Correlation analysis of the detailed regional data available for rice markets suggests that a unified market existed even for this bulk commodity in western Japan by the beginning of the eighteenth century (Miyamoto 1981). Nakamura (1990, p. 94) argues that cotton cloth, a high-value commodity, was traded in a national market with regional specialization of production by the early nineteenth century. To ensure that autarky prices most closely reflect competitive conditions, we chose 1851–53 as the autarky period for our analysis.

Assumption 2 raises the question of whether Japanese producers were

[11] From 1603 through 1868, feudal lords of the Tokugawa family ruled Japan as a quasi-military dictatorship from Edo (Tokyo). Already in decline when international trade opened up in mid-1859, the system survived for only another nine years. A rebellion of other feudal lords brought about the restoration of the central role of the emperor in 1868.

[12] See Yasuba (1987), Howe (1996), and Crawcour (1997, pp. 8–24) for more detailed English-language discussions of the Tokugawa economy. See Nakamura (1990, pp. 90–92) for a discussion of output markets, Hanley and Yamamura (1977, p. 86) for labor markets, and Totman (2000, p. 250) for land markets.

TABLE 1
THE COMPOSITION OF JAPANESE TRADE, 1868–75

Product	Imports (%)	Exports (%)
Agricultural nonfood:		
Silk		35.9
Silkworm eggs		15.7
Other (vegetable wax and cotton)	2.2	2.7
Agricultural food:		
Tea		28.2
Rice	10.8	
Sugar	9.9	
Other foods	4.2	8.2
Other raw materials:		
Fuel (coal and charcoal)		1.9
Other	3.1	2.9
Textiles		.2
Cotton yarn	15.1	
Cotton cloth	18.4	
Woolens	19.2	
Other textiles	1.8	
Other manufactures		4.3
Weapons and ammunition	2.7	
Machinery and instruments	1.4	
Miscellaneous manufactures	11.2	

SOURCE.—Japan Bureau of Revenue (1893).
NOTE.—The trade shares of each commodity group are based on total imports and exports for the period 1868–75.

price takers in international markets. Table 1 provides a summary of the composition of Japanese trade for 1868–75, the period in which comprehensive trade data are first available. Consider first the markets for imports. One-third were agricultural commodities such as beans, sugar, vegetable oil, and rice. Latham and Neal (1983) document the size of international markets for agricultural commodities such as rice and wheat in the last third of the nineteenth century; the volume traded dwarfed any demand from Japan. Another one-half of imports were cotton and woolen textiles. Japanese imports came primarily from England, where the Japanese demand was again a fraction of exports to India and China. The remaining imports of miscellaneous manufactured goods would all have been a fraction of international demand during the early period of open trade. Exports were virtually all of agricultural origin and were produced by small farms under highly competitive conditions. Sugiyama (1988, chaps. 4, 5) provides a detailed account of silk, silkworm egg, and tea production, which accounted for about 80 percent of Japanese exports. Indian and Chinese silks competed with Japanese silks in the three main import markets: Britain, France, and the United States. Japanese silks took up 15–20 percent of imports into these markets during the first two decades after the opening up to trade. Western governments effectively countered early efforts of

the Japanese authorities to manipulate the supply of silk available for export. The United States rapidly became the main market for Japanese green tea. It faced competition from Chinese green tea, black tea, cocoa, and coffee. Competitive relationships also prevailed in the merchant community that handled the import and export trade. It included 25 western merchant houses and a growing Chinese merchant community that offered the Europeans stiff competition (von Scherzer 1872, pp. 369–72).

For those familiar with Japan today, assumption 3—exports were not subsidized—may appear the most untenable. In actuality, during the 20 or so years after trade opened up, government efforts to develop export industries remained modest. Treaties held tariffs to a minimum, and straitened finances precluded subsidies. The government actually levied modest export *taxes* of 3–4 percent ad valorem on tea and silk.[13]

The final assumption, 4, asserts that had it remained closed, Japanese growth would not have been biased toward importables during the nine years from the opening up to trade to 1868, when the free-trade regime was fully in place and comprehensive trade data are available. Given the impetus of economic growth up to 1859, a shift away from exportables toward the goods that accounted for three-quarters of imports (rice, sugar, woolens, and cotton cloth and yarn) in the subsequent nine years would have been unlikely. Contemporary commentators offer one assessment of the momentum of growth just prior to the opening up to trade. They correctly identified the goods that actually became the leading exports of the 1860s, including tea, camphor, and copper. Only raw silk was excluded because of doubts that production could be expanded substantially beyond what the Japanese consumed under autarky (Hildreth 1855, p. 560). Accounts of the last century of the Tokugawa economy likewise stress the ongoing shift of land and labor out of rice into tea and raw silk (Howe 1996, pp. 40–41). The lack of land with a suitable climate constrained increased production of another key import, sugar, and the absence of any sheep in Japan prior to the opening up to trade ruled out the domestic production of woolens. The low productivity of the hand technologies available to the spinning sector constrained any substantial expansion of cotton textile production. The weaving sector had already achieved the productivity gains possible with the adoption of the vertical loom and the emergence of specialized weaving and spinning enterprises by the 1840s (Nakamura 1990).

It is also possible, but not likely, that the Japanese could have used the available information on western technology to shift production toward the machine-made products of the west such as cotton yarn and cloth. Even before the 1850s, western technologies were being imple-

[13] The estimated rates pertain to the early 1870s (see Sugiyama 1988, p. 35).

mented in Japan, but only with great difficulty. Information on Dutch agricultural techniques was available to the small numbers of those who spoke Dutch, but there is no evidence of commercial adoption of western technologies in manufacturing. On the basis of his reading of the attempts of some feudal lords to manufacture cannons and build ships according to western plans in the 1850s, Pauer (1987) argues that the limited technological expertise and the skill set available to the Japanese during the Tokugawa period precluded rapid adoption of western technologies. It is notable that it took 15 years after 1859 before Japanese weavers of cotton cloth began to use the flying shuttle, a technology offering ready productivity gains that had been in use in England since the eighteenth century. The importation and then adaptation of western technologies to Japanese conditions that characterized early industrialization got under way only after 1880.

IV. Empirical Implementation

A. *Hypotheses*

The methodology of our historical-empirical exercise is based on a simple decision-theoretic framework. As discussed in Section II, the theory implies a concrete hypothesis about the sign of Japan's net export vector valued at autarky prices:

$$H_0: \mathbf{p}_1^a\mathbf{T} < 0. \tag{4}$$

To evaluate the empirical validity of this claim, we need to specify an appropriate counterclaim.

Ruling out that the sign of $\mathbf{p}_1^a\mathbf{T}$ is random, we obtain the following counterclaim:

$$H_1: \mathbf{p}_1^a\mathbf{T} \geq 0. \tag{5}$$

Although hypothesis H_1 is not the prediction of any alternative theory of international trade, the data could "choose" H_1 instead of H_0. Given that the Japanese economy fulfills the textbook assumptions of a small neoclassical economy, evidence in favor of H_1 would require some reconsideration of the theory.

If we were in the possession of "perfect data" on Japan's trade and autarky price vectors, we would be rather confident in making a correct decision with regard to whether Japan's pattern of trade after it opened up followed the law of comparative advantage (i.e., H_0 is true) or not. However, measurement errors that arise from both the "timing of the experiment" and the incompleteness of autarky price data could increase the likelihood of making a wrong decision. Our decision is based on an approximation $\tilde{\mathbf{p}}_1^a\tilde{\mathbf{T}}$ of the true (unknown) inner product $\mathbf{p}_1^a\mathbf{T}$.

The "autarky" and "free-trade" regimes of the model correspond to about two decades of historical time. The goal of keeping the measurement errors as small as possible guided the selection of the two periods used for collecting the price and trade data to construct $\tilde{\mathbf{p}}_1^a\tilde{\mathbf{T}}$. In addition, we used approximations for the missing autarky price data that would, ex ante, make the inner product more likely to be positive and, consequently, weigh the decision in favor of hypothesis H_1. The aim of this strategy was to reduce the "likelihood" of erroneously accepting hypothesis H_0.

Although the specification of the alternative hypothesis given in (5) serves as a guide for approximating missing data points in calculating the inner product, it does not lend itself to any probability statements. An alternative counterclaim to the prediction that $\mathbf{p}_1^a\mathbf{T}$ is negative is that the sign of the inner product is a random event. It seems reasonable to assume that, in the case of randomness, the occurrence of a negative sign is as likely as the occurrence of a positive sign. This leads us to the second alternative hypothesis:

$$H_2\text{: } \mathbf{p}_1^a\mathbf{T} \text{ is random with } \Pr(\mathbf{p}_1^a\mathbf{T} < 0) = \tfrac{1}{2}, \tag{6}$$

where $\Pr(\cdot)$ denotes the probability measure. Since the alternative hypothesis (6) claims that the sign of the inner product is determined by the toss of a (balanced) coin, the null hypothesis in (4) should now be interpreted as saying that the inner product is negative with probability one. Assuming that the annual estimates are independent and are drawn from the same distribution, we can calculate the smallest level of significance for which the given data points would lead us to reject the randomness hypothesis given in (6).

B. Data Description

For the analysis of autarky prices, data from the period 1851–53 appear to offer the best representation of the "autarky regime" just prior to the opening up to trade. Already by the 1840s, economic activity was organized in fairly competitive markets since the economy had time to respond to the easing of the feudal restrictions that started decades earlier. The early 1850s precede the first treaty between Japan and the West in 1854.[14] For the "free-trade regime" we selected the period of 1868–75. With this choice we aimed to strike a balance between assuring the reliability of the trade data, which increases with time after the

[14] The first treaty simply secured the Americans access to two ports that would be available as coaling stations and as safe havens for shipwrecked sailors. Debate over whether or not to open trade continued through the treaty of 1858, which opened the country up (Jansen 2000, pp. 174–85).

opening up of Japan, and effectively capturing the mix of Japanese imports and exports that best reflects the production possibilities existing just prior to the end of autarky.

For the construction of the autarky price vector, we identified three groups of commodities. The first group of commodities includes exportables and importables for which we could identify reasonably close domestic substitutes and for which we could obtain autarky price information. For these commodities, we relied on the continuous price data that are available from 1851 through the early 1870s from a variety of Japanese-language sources (Kinyu Kenkyukai 1937; Miyamoto 1963; Ono 1979; Yamazaki 1983; Mitsui Bunko 1989). These sources draw on merchant account books, the records of large trading houses such as Mitsui, and the records of producers. The available price series cover about 65 commodities. In cases in which the prices of downstream importables were not available, we used the price of the upstream raw material or intermediate good.[15] For products with quality differences, such as silk and tea, the decision rule dictates that the estimates err on the side of using price data for the higher-quality variety.[16] Contemporary European-language publications and more recent research provide information on the prices of some additional goods just at or before the opening to trade.[17] Overall, commodities for which autarky price information is available make up two-thirds of imports by value in 1868–75 and about 95 percent of the value of exports.

A second group of commodities includes goods (primarily woolens) that were not produced in Japan under autarky. Pricing of woolens must take account of the surge in the relative price of woolens that began in 1860 with the American Civil War and the drop-off in American exports of cotton. James (1857) provides information on the price of Orleans cloth (which was relatively inexpensive) and middle-quality camlets in 1854. These prices are lower than the prices quoted for similar goods in the consular reports for Shanghai for 1858 (United Kingdom 1861,

[15] We substituted a simple unfinished cloth (*siraki*), for which a complete description was available, for all other finished cotton cloths. This cloth had about the same weight and quality as the chief unfinished cloth import, shirtings. Unfinished cloths of a higher quality sold for from 20 percent (bleached) up to 300 percent (velvets) more. Applying the relative prices found in Brennwald (1865, pp. 27–32) and von Scherzer (1872, p. 394) to imports in 1868–75 suggests that our approach undervalued the average autarky price of imports of cotton cloth by at least 20 percent.

[16] This approach was most important for the choice of a price for tea—where the prices available varied on the order of 10 times—and the price of raw silk. We used the highest price of "first-quality" tea and the price for the high-quality fine Maebashi silk (Sugiyama 1988, p. 90).

[17] About 17 commodities fall in this group. They include minor exports such as seaweed, gall puffs, awabi shells, vermicelli, and camphor. The sources are United Kingdom (1861) for the ports of Nagasaki and Kanagawa in 1859 (June and December) and in 1860 (January); von Scherzer (1872, p. 262) for silkworm eggs; and Huber (1971) for the price of cotton yarn.

p. 517). Von Scherzer (1872, pp. 396–97) provides information on the relative market price of other woolen imports; these price data suggest that using the camlet prices for middle- and higher-quality cloths and using the price of Orleans for the lower-quality cloths that appear in the statistics will provide reasonable minimum estimates of the value of these imports.[18]

Finally, the calculation of the inner product required estimating the prices of a third group: the one-twentieth of exports and one-sixth of imports for which there were domestic substitutes, but for which price information could not be found in Japanese or contemporary European sources. Approximating the prices of this group of traded goods circa 1851–53 relied on adjusting the actual unit values available from the trade data in 1868–75 for changes in the prices of imports and exports from the early 1850s. Sugiyama (1988) notes that contrary to the practice of many European countries at the time, the valuations of imports and exports reflected actual invoiced values. Exports were valued at the price at the point of export, whereas imports were valued at the price prior to shipment to Japan. The adjustment uses the indices of import and export prices found in Shinbo (1978, table 5-10).

The trade data are taken from the import-export statistics collected by the Meiji customs at the treaty ports for 1868–75 (Japan Bureau of Revenue 1893). The statistics include over 250 separate goods. Alternative series are available from the reports of the British consuls in the ports, but these data lack consistent recording of quantities and the detail found in the official statistics. A check of the British data from 1869 with the official statistics found only minor discrepancies that would have no material bearing on the estimates presented here.[19]

C. Empirical Findings

Figure 4 illustrates the price changes of the key tradable goods after the opening up to trade. It presents a scatter diagram of the net exports in 1869 graphed in relation to the change in prices from 1851–53 to 1869.[20] High inflation after the opening up to trade meant that all prices

[18] The most important import that will be undervalued using this procedure is "woolen cloths," which had a unit value in the late 1860s that was four times the unit value of camlets.

[19] See Sugiyama (1988, pp. 44–48) for a general discussion of Japanese trade statistics during the first decades after the opening up to trade. The British recorded quantities of cotton and woolen cloth in "pieces" instead of yards, a practice that substantially increases the potential error in matching net export data from the consular sources with autarky prices.

[20] After 1859, Japan experienced substantial price inflation. For that reason we have normalized all price changes using the price index of nontradables from Shinbo (1978, table 5-10). Net exports are valued at autarky prices.

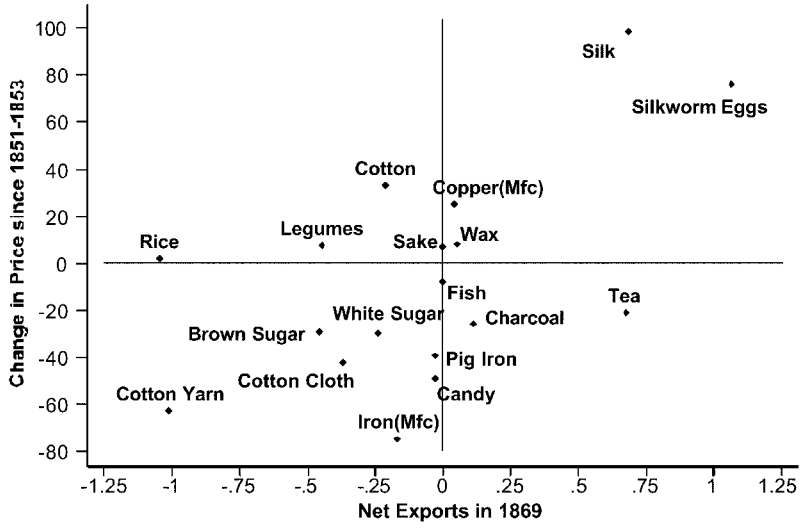

FIG. 4.—Net exports and price changes for 1869. Source: Japan Bureau of Revenue (1893) for trade data and Kinyu Kenkyukai (1937), Miyamoto (1963), Ono (1979), Yamazaki (1983), and Mitsui Bunko (1989) for price data.

rose substantially, so that the graph expresses price changes adjusted for the increase in the price of nontradable goods. The prices of major exports such as products of the silk industry (silk and silkworm eggs) and minor exports such as copper manufactures, sake, and vegetable wax all increased; in some cases they almost doubled. The relative price of key imports such as sugar, cotton cloth, cotton yarn, and iron products displayed substantial declines. The increase in the price of rice and legumes may reflect poor weather conditions, and the increase in the price of cotton may stem from the disruption of cotton markets in the wake of the American Civil War.

Table 2 contains the empirical results that incorporate all of the price and net export data. Each column evaluates the trading vector of a particular year $\tilde{\mathbf{T}}_i$ ($i = 1868, \ldots, 1875$) at the same autarky price vector $\tilde{\mathbf{p}}_1^a$. The rows report the constituent components of $\tilde{\mathbf{p}}_1^a \tilde{\mathbf{T}}_i$: the value of net imports or net exports for which autarky prices are available (rows 1 and 4), the value of imports of woolens (row 2), and the value of net imports and net exports for which autarky price data are not available (rows 3 and 5). All valuations are in terms of the ryō, a currency that was replaced by the yen at par in 1871. The autarky price prediction of the law of comparative advantage holds in all of the eight trading years. Note that the result holds in the year of a surplus on current account (1868) as well as during a deficit. Although estimates of gross domestic

TABLE 2
APPROXIMATE INNER PRODUCT IN VARIOUS TEST YEARS (Millions of Ryō)

COMPONENTS	YEAR OF NET EXPORT VECTOR							
	1868	1869	1870	1871	1872	1873	1874	1875
1. Imports with observed autarky prices	−2.24	−4.12	−8.44	−7.00	−5.75	−5.88	−7.15	−7.98
2. Imports of woolen goods	−.98	−.82	−1.29	−1.56	−2.16	−2.50	−1.56	−2.33
3. Imports with approximated autarky prices (Shinbo index)	−1.10	−.95	−.70	−.85	−1.51	−2.08	−1.60	−2.65
4. Exports with observed autarky prices	4.07	3.40	4.04	5.16	4.99	4.08	5.08	4.80
5. Exports with approximated autarky prices (Shinbo index)	.09	.03	.07	.07	.15	.07	.11	.10
Total inner product (sum of rows 1–5)	**−.18**	**−2.47**	**−6.31**	**−4.17**	**−4.28**	**−6.31**	**−5.11**	**−8.06**

SOURCE.—For sources of price data, see Sec. IV*B* and n. 17. For rows 3 and 5, current silver yen values are converted to values of 1851–53 by deflating them with the price indices for exports and imports found in Shinbo (1978, table 5–10).

NOTE.—All values are expressed in terms of millions of ryō. The ryō equaled about $1.00 in 1873 and was equivalent to the yen when it was introduced in 1871. The estimates are of the approximation of the inner product ($\bar{\mathbf{p}}_i'\mathbf{T}$) valued at autarky prices prevailing in 1851–53. An explanation of the assumptions underlying the approximation is contained in the text.

product for the autarky period covered by this study are not available, evidence on wages and the price of rice helps place the estimates of the inner product in perspective. For example, the (lower-bound) estimate of 180,000 ryō based on the vector of trade in 1868 would have been equivalent to the annual earnings of about 5,000 skilled workers in construction in Tokyo or 5,600 workers in agriculture near Osaka.[21]

Under the maintained hypothesis that the annual estimates are independent and stem from the same distribution, we can test the hypothesis H_0 against the alternative hypothesis H_2 that the inner product is purely random. For a probability statement, the problem at hand suggests focusing on the *p*-value, defined as the smallest level of significance for which the given sample observations would lead us to reject the randomness hypothesis. With eight negative entries in a sample size of eight, the *p*-value is about 0.4 percent.[22]

[21] Skilled construction workers in the early 1850s earned about 30 ryō per year (Kinyu Kenkyukai 1937, pp. 325–26). Yasuba (1986) notes that workers in agriculture earned about 2.94 *koku* of rice annually in the mid-1850s; 180,000 ryō would buy 16,500 *koku* (2,200 metric tons) of rice.

[22] The *p*-value is exactly 1/256, where 1/256 is the probability of obtaining eight heads in eight tosses with a balanced coin.

V. Concluding Remarks

The last decade has witnessed an increased interest in exploring the empirical content of neoclassical trade theory. In particular, the Heckscher-Ohlin model—the "backbone of traditional trade theory" (Leamer and Levinsohn 1995, p. 1345)—has been the primary target of empirical research. The empirical trade literature typically aims at estimating the "accuracy" of the predictions of the Heckscher-Ohlin model rather than testing a specific hypothesis.

To our knowledge of the literature, this paper provides the first direct test of the theory of comparative advantage in its most general formulation. It is "direct" since the underlying hypothesis is formulated in terms of a country's relative autarky prices. The testable hypothesis derived from this approach places no restriction on what accounts for comparative advantage, whether factor endowments, technologies, tastes, or a combination of them. However, as a trade-off, the hypothesis provides no information about the commodity composition of trade: which goods will be exported and which will be imported.

One central theme of this paper is that Japan's nineteenth-century trade liberalization provides a "natural historical experiment" within which to test the autarky price prediction of comparative advantage trade theory. The historical narrative demonstrates that the Japanese economy during the time period of our investigation was compatible with the assumptions of the underlying theory.

As has been noted elsewhere, the domain of economic theory surely encompasses more than the recent past, and there are distinct advantages to exploiting the rich veins of historical experience to test the validity of theory (McCloskey 1976). The case of Japan provides a natural experiment that occurs in an environment that is transparent by any reasonable measure. External pressure forced a low tariff structure on Japan and precluded the use of other nontariff barriers that are part and parcel of contemporary trading regimes. The detail of Japan's trading statistics allowed a clear identification of the commodities actually entering trade. The robustness of our findings suggests that the autarky price formulation of comparative advantage is a coherent and insightful theory that can also be validated empirically.

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