

Classical Ricardian Theory of Comparative Advantage Revisited

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Abstract

According to the classical Ricardian theory of comparative advantage, relative labor productivities determine trade patterns. The Ricardian model plays an important pedagogical role in international economics, but has received scant empirical attention since the 1960s. This paper assesses the contemporary relevance of the Ricardian model for US trade. Cross-section seemingly unrelated regressions of sectoral trade flows on relative labor productivity and unit labor costs are run for a number of countries *vis-à-vis* the United States. The coefficients are almost always correctly signed and statistically significant, although much of the sectoral variation of trade remains unexplained.

1. Introduction

The classical Ricardian model is often used to exposit the principle of comparative advantage. Despite its pedagogical importance, this model has been almost completely ignored in the professional literature in recent decades. The classical emphasis on productivity differences and labor costs has been supplanted by the neoclassical (Heckscher–Ohlin) focus on factor endowments. The paucity of work is such that leading international trade textbooks continue to cite the results from MacDougall (1951), Stern (1962), and Balassa (1963) when discussing the empirical evidence on the Ricardian model.¹ A recent survey states: “We are unaware of any recent work testing or estimating the applicability of the Ricardian model” (Leamer and Levinsohn, 1996).

This neglect of the Ricardian model reflects several perceived limitations. Leamer and Levinsohn (1996) view the model as too simple for serious empirical analysis. It is true that the textbook Ricardian model ignores factors of production besides labor, and has the unrealistic implication that countries specialize in the production of tradable goods. But we believe that these limitations are offset by some important advantages. First, since capital and raw materials are much more tradable internationally than is labor, the latter is likely to have a disproportionate influence on comparative advantage. Second, the Ricardian emphasis on sector-specific technological gaps between countries is suggested by recent international comparisons of productivity. Third, older tests of the Ricardian model were highly successful. Fourth, the simplicity of the Ricardian model is in itself a strength and explains its pedagogical appeal. In any event, it is surely worth knowing how well one of the basic pedagogical models performs empirically with more recent data.

In this paper, we update and extend the classic tests of the Ricardian model (MacDougall, 1951; Stern, 1962; Balassa, 1963) using a much larger group of countries and years. We use the OECD STAN (Structural Analysis Industrial) database to obtain

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trade flows, productivity, and unit labor costs for about 40 manufacturing sectors for a number of OECD countries, as well as Mexico and Korea from 1970 to 1992. To examine the link between trade patterns and relative labor costs, we run cross-sectional seemingly unrelated regressions of sectoral trade flows on sectoral relative labor productivity and unit labor costs for a number of countries *via-à-vis* the United States.

2. Reassessing the Ricardian Model

The Basic Ricardian Model

The Ricardian model focuses on labor productivity and labor costs as the determinants of comparative advantage. Let a_{ij} represent unit labor requirements (the inverse of productivity), for sector i in country j :

$$a_{ij} = L_{ij} / Q_{ij}, \tag{1}$$

where Q is value-added, and L is labor employment. The marginal product of labor ($1/a_{ij}$), and hence unit labor requirements (a_{ij}), are assumed to be constant with respect to variations in L_{ij} . The assumption of constant marginal product is not in itself critical, but productivity differences between countries must be large enough that they are not eliminated by trade.

Competitiveness of sector i in country j compared with country k also depends on wages (w_{ij} and w_{ik}) and the bilateral exchange rate (e_{jk}), which determine relative unit labor cost, denoted by c_{ijk} in a common currency:

$$c_{ijk} = a_{ij}w_{ij} / a_{ik}w_{ik}e_{jk}. \tag{2}$$

Country j will specialize in goods where $c_{ijk} < 1$ and import goods where $c_{ijk} > 1$. In most expositions of the Ricardian model, labor is assumed to be homogeneous and perfectly mobile between sectors. Hence, wages are equal across sectors within a country. We relax this assumption of intersectoral wage equality in our empirical analysis.

It is not straightforward to implement the Ricardian model in a multicountry setting. Consider the n -good, n -country case, as in Jones (1961).² Jones shows that an optimal assignment involves minimizing the product of the unit labor requirements (or equivalently, of the unit labor costs, if wages are allowed to differ across sectors). Suppose that the commodities are indexed such that the optimal assignment for country i is to produce good i . Consider all patterns of complete specialization; i.e., each country is assigned one good. Jones's criterion is that the optimal assignment a_{ii} must be such that

$$\prod_{i=1}^n a_{ii} < \prod_{i=1}^n a_{ij} \quad \text{for any } j \neq i, \text{ and all } j \text{ different from each other.} \tag{3}$$

This can be understood intuitively by noting that if (3) is violated, world output of at least one good can be increased by reallocating production patterns across countries and goods, since unit labor requirements are not minimized. In the two-country, two-good case, Jones's criterion collapses to the textbook Ricardian result that country 1 has a comparative advantage in good 1, and country 2 in good 2, if $a_{11}/a_{12} < a_{21}/a_{22}$.

It is important to note for our purposes that bilateral comparisons of comparative advantage are necessary although not sufficient conditions for global optimality. This can be observed by noting that a bilateral violation of comparative advantage implies that the global condition (3) does not hold. This provides some justification for focusing on bilateral trade patterns, as we do below.

Strengths and Weaknesses of the Ricardian Model

Incomplete specialization Perhaps the most problematical feature of the simple Ricardian model, from an empirical point of view, is the implication that countries specialize completely in tradable-goods production, except in cases when a small country cannot satisfy the demand of a large country. In practice, import-competing sectors rarely disappear in the face of foreign competition. There are two possible routes to reconciling incomplete specialization with differences in labor productivity: product differentiation and disequilibrium effects.

A disequilibrium interpretation of the Ricardian model is that price and quantity arbitrage is incomplete, resulting in incomplete specialization in the short run. In long-run equilibrium, either complete specialization or equality of unit labor costs would be attained, but the process of adjustment may be very slow. There is some empirical support for the existence of sustained disequilibria in the markets for internationally traded goods. In a classic study, Isard (1977) finds persistent deviations from the law of one price in US and German export prices among highly disaggregated industrial sectors. Giovannini (1988) finds deviations from purchasing power parity even among basic “commodity” manufactured goods, such as ball bearings, screws, and nuts and bolts. The importance of disequilibrium prices and quantities in international trade is further documented in the experimental study of Nousseir et al. (1995). The disequilibrium view implies that relative unit labor costs are preferred to relative productivity as the explanatory variable, since the former allows for the possible effects of sectoral wage differences on international competitiveness.

Alternatively, incomplete specialization (and intraindustry trade) can coexist with productivity differences, owing to product differentiation. With product differentiation, differences in technology can drive interindustry trade, while intraindustry trade occurs because of product differentiation, as in Krugman (1981).³ Allowing for product differentiation also helps address Bhagwati’s (1964) objection to tests of the Ricardian theory. Bhagwati argued that if the tests of the Ricardian model are based on incomplete price arbitrage, then one should examine the link between trade prices and trade flows instead of going directly from labor costs to trade flows. With product differentiation, productivity differences, incomplete specialization, and commodity price equalization could be consistent. For example in a variant of Krugman’s (1981) model of Dixit–Stiglitz monopolistic competition, if country *X* is relatively productive in industry *A* relative to industry *B* compared with country *Y*, *X* will produce more varieties and be a net exporter of good *A*, yet the price of each variety of good *A* will be equalized across countries by trade. In such a framework, there is no link between observed post-trade relative product prices and trade patterns, but there is a link between relative labor productivity and trade.

Petri (1980) introduces incomplete specialization in a Ricardian model in a related way. He observes that even finely disaggregated trade classifications may cover different products. Different countries may produce the same commodity as classified by trade statistics, because those statistics aggregate products with different production characteristics. Davis (1995) shows that intraindustry trade can be explained with a hybrid Heckscher–Ohlin–Ricardo model. Consider two goods which have identical factor intensities at any given factor prices—“perfect intraindustry goods” in Davis’s terminology. Davis point out that Hicks-neutral differences in technologies across countries in these goods, however small, will then dictate the pattern of specialization. Hence, comparative advantage can have a Ricardian character and lead to intraindustry trade.

Technology and labor costs as the source of comparative advantage The classical model's focus on labor costs seems to leave out other important determinants of comparative advantage, particularly the costs of capital and of other intermediate inputs. There are several big advantages to emphasizing the role of labor, however. First, labor is the main nontradable primary input. Capital and natural resources are much more mobile than labor, and as a consequence international differences in labor costs are much greater than in other factors' costs.⁴ As Jones (1980) has emphasized, for highly mobile factors such as capital and raw materials, absolute rather than comparative advantage becomes relevant for the location of production.⁵ The location of perfectly mobile factors is endogenous and cannot be considered an independent source of comparative advantage. Similarly, Ferguson (1978) shows that comparative advantage takes on a Ricardian character in a standard two-factor model under perfect international capital mobility. In the special case where technological differences between countries are due to differences in the efficiency of labor, Ferguson (1978) demonstrates that relative labor productivity is the sole determinant of comparative advantage, and that the MacDougall (1951) approach to testing comparative advantage is valid. It is true that under some conditions capital mobility and trade may be perfect substitutes insofar as trade results in factor-price equalization, so capital–labor ratios may determine trade patterns even under perfect capital mobility. But if there are industry-specific technological differences between countries—as emphasized in the Ricardian model—factor prices are less likely to be equalized by trade alone. In short, international capital mobility implies that a theory of comparative advantage based on labor costs is less circumscribed than appears at first, although relative labor costs are the sole determinant of comparative advantage only in special cases.

Second, recent comparative studies have identified large variations in sectoral labor productivity across countries (Maskus, 1991; Caves et al., 1992; McKinsey, 1993; Dollar and Wolff, 1993; Wolff, 1993; Van Ark and Pilat, 1993; Jorgenson, 1995). There have been few attempts to relate these differences in relative productivities to trade flows, however, as the Ricardian model suggests.⁶

Table 1 illustrates the differences in productivity in manufacturing by sector for a few of the countries studied in this paper.⁷ Clearly, countries differ sharply not only in their overall productivity levels, but also in the sectoral distribution of productivity. In particular, the careful comparisons of the United States, Japan, and Germany in McKinsey (1993) identified sector-specific production and organizational practices as the most important factors accounting for industry productivity differentials. This suggests that technological differences are not neutral across sectors, in contrast to Treffler's (1993, 1995) amendment of the Heckscher–Ohlin model to include neutral technological differences. Third, as a practical matter, data on labor costs are much more readily available than for other costs of production.

Furthermore, as Deardorff (1984) points out, the productivity and factor-endowments-based approaches to comparative advantage are not necessarily inconsistent. Although most expositions of the Ricardian model assume that differences in labor productivity arise from technological differences, differences in relative factor endowments could give rise to productivity differences, if the endowment differences are large enough to force complete specialization, or if barriers to trade preclude complete price arbitrage across countries. It would be interesting to attempt to separate out the influences of differences in technology and in factor endowments on labor productivity, but this is not easy. The theory of endogenous growth suggests that technological progress and capital accumulation are inextricably intertwined. For example, in Romer's (1990) model, technological progress is embodied in new varieties of capital

Table 1. Real Value Added Per Person Engaged, 1990, by Sector (US = 1.0)

	Japan	Germany	Korea	Mexico
Total manufacturing	0.88	0.86	0.44	0.38
Food, beverages & tobacco	0.51	0.88	0.53	0.33
Textiles, apparel & leather	0.52	0.83	0.46	0.36
Wood products & furniture	0.28	0.68	0.85	0.32
Paper, paper products & printing	0.81	0.79	0.57	0.52
Chemicals, excl. drugs	0.74	0.54	0.29	0.35
Drugs & medicines	0.63	0.44	0.38	0.27
Rubber & plastic products	1.15	0.87	0.37	0.39
Non-metallic mineral products	0.76	1.05	0.83	0.34
Iron & steel	1.82	0.89	1.09	0.76
Non-ferrous metals	1.30	0.97	0.74	0.33
Fabricated metal products	1.18	0.70	0.34	0.33
Non-electrical machinery	1.76	0.94	0.34	0.38
Office & computing equipment	1.10	1.06	0.20	0.44
Electrical machinery	1.99	1.26	1.20	0.69
Radio, TV & communication equip.	0.74	0.65	1.06	0.18
Shipbuilding & repairing	1.36	0.91	0.32	0.65
Motor vehicles	1.82	1.08	0.56	0.50
Aircraft	1.31	0.52	NA	NA
Other transport equipment	1.31	0.38	NA	0.08
Professional goods	1.02	0.67	0.32	0.31
Other manufacturing	2.34	0.85	0.23	0.34

Source: OECD STAN database and authors' calculations, as described in the text. Uses ICOP PPP exchange rates to convert to a common currency.

goods. The theory of endogenous growth reinforces the result from neoclassical models that technological progress provides an incentive for further capital accumulation. Although growth theory focuses on macroeconomic aggregates, such processes are also at work at the sectoral level. Moreover, we believe it is useful and interesting to study the effects of productivity on trade, even if the ultimate causes of the productivity differences are unknown.

The voluminous empirical research on the factor-endowments theory has yielded mixed results.⁸ In contrast, the classic MacDougall (1951) test of the Ricardian model and the follow-ups by Stern (1962) and Balassa (1963), all on US and UK trade with third countries, were quite successful, but there have been few studies since then. We aim to fill this gap in the literature.

3. Bilateral Comparative Advantage and Trade Patterns

Specification

This section presents applications of the Ricardian theory for countries and time periods not previously examined. We tested the Ricardian model for the following pairs of countries *vis-à-vis* the US: Japan, Germany, France, UK, Italy, Canada, Australia, Korea, and Mexico. This is a diverse group of countries constituting a large part of US trade. The main data sources are the OECD's Structural Analysis Industrial (STAN) and Bilateral Trade (BTD) databases.⁹

Dependent variable For each of these bilateral trade pairs, depending on data availability, two alternative measures of trade flows were used: bilateral trade balances and export ratios.

Export ratios The MacDougall (1951), Stern (1962), and Balassa (1963) studies used the ratio of US to UK exports as the dependent variable. MacDougall and Stern used total exports, while Balassa used exports to third markets, excluding their bilateral trade. Balassa excluded bilateral trade on the grounds that the latter is affected by the relative size of US and UK trade barriers. Balassa's sample is from 1950 when tariffs were much higher than in the post-1970 period, which is the sample period here. On the other hand, transportation costs to third markets may not be identical, whereas they should be nearly identical for bilateral trade (the distance from the US to the UK is the same as from the UK to the US), so the Balassa focus on third markets seems questionable in a world where transportation costs are significant relative to tariffs and other barriers. Also, in most cases trade barriers will alter the magnitude of trade rather than its direction, so bilateral trade flows should still reflect comparative advantage despite the presence of asymmetrical barriers. Furthermore, if bilateral trade is an important part of total trade, omitting the former leaves out part of what one seeks to explain. If bilateral trade is a small part of total trade, this measure will be very similar to that of Balassa.¹⁰ For these reasons, we use the overall export ratio as in MacDougall and Stern, instead of the ratio of exports to third markets. Unfortunately, for this specification, Mexico and Korea could not be included, because the STAN database currently does not include trade flows for these countries.¹¹

Bilateral net exports This is a more natural way of assessing comparative advantage, and bilateral trade balances are often the focus of popular attention. It is also more appropriate theoretically than export ratios, based on the Jones (1961) criterion discussed above.¹² A practical disadvantage of this specification is that we are confined to the 26-sector BTD classification instead of the 49-sector STAN classification. On the other hand, Korea and Mexico can now be included.

Independent variables MacDougall (1951) and Balassa (1963) used relative productivity, a_{ik}/a_{ij} , as the main independent variable.¹³ Stern (1962) tried both relative unit labor costs, c_{ijk} , and relative productivity as the explanatory variable, as we do here.

To compare levels (as opposed to rates of change over time) of real outputs across countries, they must be converted to a common currency.¹⁴ The market exchange rate is likely to be misleading, because of the well-known failure of purchasing-power parity to hold, at least in the short run. Instead, a purchasing-power-parity (PPP) exchange rate is needed. Obtaining appropriate disaggregated PPPs is difficult. Given the uncertainties involved, we have chosen to experiment with three alternative PPPs: (1) common PPPs for all sectors; (2) sector-specific Heston–Summers final expenditure PPPs from the United Nations International Comparison Project (ICP); and (3) sector-specific manufacturing PPPs from the University of Groningen's International Comparison of Output and Productivity (ICOP) project.¹⁵ The labor compensation data used to generate unit labor costs includes both wages and nonwage benefits.

All variables are in logs. The independent variable was lagged one year to allow for slow adjustment and to avoid any simultaneity problems, although this made little difference to the results in most cases. Thus the equations to be estimated are:

$$\log(X_{ij}/X_{ik}) = \alpha_{jk1} + \beta_{jk1} \log(a_{ik}/a_{ij})_{-1} + \varepsilon_{ijk1}, \quad (4)$$

$$\log(X_{ij}/X_{ik}) = \alpha_{jk2} + \beta_{jk2} \log c_{ijk-1} + \varepsilon_{ijk2}, \quad (4')$$

$$\log(X_{ijk}/M_{ijk}) = \alpha_{jk3} + \beta_{jk3} \log(a_{ik}/a_{ij})_{-1} + \varepsilon_{ijk3}, \quad (5)$$

$$\log(X_{ijk}/M_{ijk}) = \alpha_{jk4} + \beta_{jk4} \log c_{ijk-1} + \varepsilon_{ijk4}, \quad (5')$$

where X_{ij} is total exports of good i by country j , X_{ijk} and M_{ijk} are bilateral exports and imports between country j and country k , and -1 denotes a one-period lag.

It might at first appear that these equations relate trade flows between countries j and k in sector i to absolute advantage a_{ik}/a_{ij} , rather than comparative advantage $(a_{ik}/a_{ij})/(a_{mk}/a_{mj})$ relative to other sectors m . But this is not so. The regression coefficients β capture the effects of deviations from the sample means. Thus, for example, a positive β in equation (5) indicates that in those industries i where a_{ik}/a_{ij} is low relative to the sample mean a_{ik}/a_{ij} , country j tends to have larger bilateral net exports to country k than sample mean bilateral jk net exports. So equations (4) and (5) are testing for the effects of comparative rather than absolute advantage.

Both time series and cross-section regressions are possible with this dataset, as the data cover 1970–92. The emphasis here is on cross-section regressions at a point in time, since the time-series responsiveness of sectoral trade flows to unit labor costs has been analyzed elsewhere (Golub, 1994), and in any case the cross-section results are of more interest at a disaggregated level. Much of the short-run variation over time in unit labor costs is due to exchange rate changes, which are common to all sectors, so there is less benefit to disaggregation than for cross-sectional analysis. At the cross-section level, macroeconomic factors which alter the overall trade balance are unlikely to have much influence on the results, as all sectors should be affected in the same direction.

The errors in the annual cross-section regressions are likely to be highly correlated across years since trade patterns change slowly over time.¹⁶ To take advantage of the correlation in the error terms in the different years, a “seemingly unrelated regression” (SUR) procedure was used, with the annual cross-section regressions estimated simultaneously. The number of years over which the SUR equations were estimated is not the same for all countries, and depends on the availability of data in the STAN database. The coefficients on unit labor costs in the SURs were constrained to be equal over time, but the constant terms were allowed to differ, in recognition of macroeconomic shocks which affect all sectors in the same direction.¹⁷ Ordinary least squares was also estimated for each individual year and country.

In estimating equations (4) and (4'), the number of sectors was reduced from 49 to 39 after eliminating those cases where the subsectors add up to the sectoral total, and petroleum refining, in which labor's share of value added is exceptionally low for all countries. Similarly, for equations (5) and (5'), the number of sectors was reduced from 26 to 21.

Results

There are four sets of equations, corresponding to the various combinations of the two independent variables (productivity and unit labor costs) and two dependent variables (export ratios and bilateral trade balances).

Relative productivity and multilateral export ratios Table 2 reports the constrained SUR results for the 39-sector sample for equation (4), for the US *vis-à-vis* the UK, Japan, Germany, Canada, France, Italy, and Australia. The dependent variable is US

Table 2. Relative Exports^a and Relative Productivity^b, for 39 Manufacturing Sectors

	Period	Unadjusted		ICP PPP		ICOP PPP	
		β_{jk}	R^2	β_{jk}	R^2	β_{jk}	R^2
US–Japan	84–90	0.33 (3.03) ^c	0.22	0.31 (2.96) ^c	0.20	0.30 (2.80) ^c	0.18
US–Germany	77–91	0.18 (4.28) ^c	0.08	0.15 (3.55) ^c	0.07	0.15 (3.80) ^c	0.05
US–UK	79–91	0.09 (2.78) ^c	0.03	0.07 (2.45) ^c	0.02	0.23 (4.48) ^c	0.12
US–France	78–91	-0.19 (-3.50) ^d	0.03	-0.24 (-3.92) ^d	0.06	0.09 (1.96) ^c	0.03
US–Italy	78–91	0.36 (5.48) ^c	0.09	0.37 (6.25) ^c	0.13	—	—
US–Canada	72–90	0.21 (5.29) ^c	0.01	0.27 (6.26) ^c	0.04	—	—
US–Australia	81–91	0.16 (2.27) ^c	0.04	0.31 (3.52) ^c	0.10	—	—

Note: $\log(X_{ij}/X_{ik}) = \alpha_{jki} + \beta_{jki} \log(a_{ik}/a_{ij})_{-1} + \varepsilon_{ijk1}$ estimated by seemingly unrelated regressions. *t*-statistics in parentheses, calculated from heteroskedasticity-consistent (White) standard errors.

^aLog of US divided by other country exports.

^bLog of US relative to other productivity.

^cThe coefficient is significant at 1% level with the correct sign.

^dThe coefficient is significant at 1% level with incorrect sign.

relative exports and the independent variable is US relative productivity, lagged one year. Results for the three alternative measures of PPP are reported.

The vast majority of the coefficients on relative productivity are correctly signed and statistically significant at the 1 per cent level. Two of the French equations are the only exceptions. The R^2 are quite low, however, except for the Japan equations.¹⁸

Sector-specific PPPs improve the results relative to the common PPPs in several cases, especially when ICOP PPPs are used. Using ICOP exchange rates, all four countries for which this PPP adjustment was possible are correctly signed and statistically significant, including France. The UK R^2 improves with ICOP PPPs, but the fit remains weaker than that reported by MacDougall (1951), Stern (1962), and Balassa (1963) for earlier years.¹⁹

When the equations are estimated year-by-year with OLS instead of SUR, the signs and magnitudes of the coefficients are usually similar to those found with SUR, but the *t*-statistics are almost always smaller, except for the Japan case where surprisingly all the year-by-year OLS coefficients and *t*-statistics are greater than with SUR. The standard errors of the SUR regressions decrease with the number of years used, thereby increasing the *t*-statistics. That is, as intended, the SUR regressions seem to be yielding more precise estimates in most cases because they make use of more information by estimating the cross-section regressions over several years simultaneously.

Relative unit labor costs and multilateral export ratios Table 3 reports the same regressions as in Table 2, except that the independent variable is now relative unit labor costs instead of relative productivity (equation (4')). Note that the predicted sign on the coefficient is now negative. The results in Table 3 are overall quite similar to those in

Table 3. Relative Exports^a and Unit Labor Costs^b, for 39 Manufacturing Sectors

	Period	Unadjusted		ICP PPP		ICOP PPP	
		β_{jk}	R^2	β_{jk}	R^2	β_{jk}	R^2
US–Japan	84–90	-0.38 (-3.37) ^c	0.26	-0.36 (-3.45) ^c	0.23	-0.33 (-2.87) ^c	0.21
US–Germany	77–91	-0.17 (-4.01) ^c	0.08	-0.14 (-3.30) ^c	0.07	-0.13 (-3.13) ^c	0.05
US–UK	79–91	-0.03 (-0.88)	0.02	-0.04 (-1.44)	0.01	-0.23 (-4.95) ^c	0.05
US–France	78–91	0.34 (5.28) ^d	0.11	0.34 (5.49) ^d	0.13	0.11 (3.88) ^d	0.03
US–Italy	78–91	-0.26 (-4.75) ^c	0.05	-0.29 (-4.90) ^c	0.08	—	—
US–Canada	72–90	0.030 (0.83)	0.01	-0.15 (-4.27) ^c	0.02	—	—
US–Australia	81–91	-0.033 (-0.48)	0.01	-0.05 (-0.75)	0.01	—	—

Note: $\log(X_{ij}/X_{ik}) = \alpha_{jk2} + \beta_{jk2} \log c_{ijk-1} + \varepsilon_{ijk2}$ estimated by seemingly unrelated regressions. *t*-statistics in parentheses, calculated from heteroskedasticity-consistent (White) standard errors.

^aLog of US divided by other country exports.

^bLog of US relative to other unit labor cost.

^cThe coefficient is significant at 1% level with the correct sign.

^dThe coefficient is significant at 1% level with incorrect sign.

Table 2 and in some cases (Japan, Germany, and Italy) are virtually identical. Again, the vast majority of cases are correctly signed and most of these are statistically significant. For some countries, though, the results are somewhat weaker with relative unit labor costs as the independent variable. For the UK, France, Australia, and Canada, at least one of the PPP specifications clearly performs better with relative productivities than relative unit labor costs. In no cases is the reverse true, so for explaining relative exports, productivity is the preferred independent variable.

Relative productivities and bilateral trade balances Table 4 turns to the case of bilateral trade balances as the dependent variable. Table 4 reports the constrained SUR results for the 21-sector sample of equation (5), for US net exports to the UK, Japan, Germany, France, Italy, Canada, Australia, Mexico, and South Korea. The independent variable is lagged relative productivity, as in Table 2. Again, in almost all cases the productivity variable is correctly signed and significant at the 1 per cent level, with the ICOP PPP cases usually dominating the other cases (Germany is an exception). Three of the coefficients in the common PPP and ICP PPP cases have the wrong sign, Korea significantly so.²⁰ The UK coefficient is incorrectly signed, even when ICOP PPPs are used. The ICOP PPP adjustment is particularly important in the case of Korea where the sign of the coefficient changes. In terms of goodness of fit, the Japan results are again among the best, along with Mexico, Germany, and Korea (when ICOP PPPs are used for the latter). The SUR results are again similar to the OLS results in most cases.

Relative unit labor costs and bilateral trade balances Finally, Table 5 presents the regressions with relative unit labor costs rather than relative productivity (equation

Table 4. Bilateral Trade Balances^a and Relative Productivity^b, for 21 Manufacturing Sectors

	Period	Unadjusted		ICP PPP		ICOP PPP	
		b_{jk}	R^2	b_{jk}	R^2	b_{jk}	R^2
US–Japan	84–91	0.14 (2.07) ^c	0.09	0.20 (2.68) ^c	0.10	0.43 (2.99) ^c	0.25
US–Germany	77–90	0.46 (8.71) ^c	0.06	0.83 (17.03) ^c	0.11	0.07 (1.32)	0.05
US–UK	79–90	-0.08 (-2.93) ^d	0.03	-0.02 (-1.41)	0.02	-0.01 (-.06)	0.02
US–France	78–90	-0.21 (-7.97) ^d	0.02	0.02 (0.52)	0.02	0.05 (2.70) ^c	0.02
US–Italy	79–89	0.26 (7.11) ^c	0.11	0.25 (7.55) ^c	0.01	—	—
US–Canada	72–89	0.41 (37.44) ^c	0.02	0.73 (77.15) ^c	0.01	—	—
US–Australia	81–91	0.72 (5.75) ^c	0.05	0.89 (7.13) ^c	0.10	—	—
US–Korea	72–90	-0.64 (-11.17) ^d	0.02	-0.12 (-6.71) ^d	0.02	0.93 (36.88) ^c	0.18
US–Mexico	80–90	0.46 (6.12) ^c	0.14	0.31 (4.21) ^c	0.10	0.56 (7.50) ^c	0.18

Note: $\log(X_{ijk}/M_{ijk}) = \alpha_{jk3} + \beta_{jk3} \log(a_{ik}/a_{ij})_{-1} + \varepsilon_{ijk3}$ estimated by seemingly unrelated regressions. *t*-statistics in parentheses, based on heteroskedasticity-consistent (White) standard errors.

^aLog of the ratio of bilateral exports to bilateral imports.

^bLog of US relative to other productivity.

^cThe coefficient is significant at 1% level with the correct sign.

^dThe coefficient is significant at 1% level with the incorrect sign.

(5')). The results are very similar to Table 4 overall, but this time there is some improvement when unit labor costs replace productivity. For Japan, Canada, and Italy there is little change, and the Australian case is slightly better with relative productivity; but for Germany, Korea, France, and the UK, at least one of the equations with relative unit labor costs does better (in the sense of correct sign and/or statistical significance of the coefficient).

Summary Overall these results are quite favorable to the Ricardian model. The overwhelming majority of the coefficients are correctly signed and most are statistically significant, although the R^2 are quite low in most instances. The Japanese results are particularly good, with relative productivity and unit labor costs explaining a substantial portion of bilateral US–Japan trade.

Low R^2 are not too surprising given the likelihood of measurement error in the independent variable, and the fact that these are purely cross-sectional regressions. Measurement error probably arises owing to the omission of non-labor costs, errors in measuring productivity and labor costs, and imperfections of the available PPPs. Measurement error in the independent variable biases the coefficients towards zero, as MacDougall (1951) stressed in his original article. In addition, however, the low R^2 suggest that there may be omitted variables. The decline in R^2 from those found in earlier periods for the US–UK case may be partly explained by the increases in capital

Table 5. Bilateral Trade Balances^a and Unit Labor Costs^b, for 21 Manufacturing Sectors

	Period	Unadjusted		ICP PPP		ICOP PPP	
		b_{jk}	R^2	b_{jk}	R^2	b_{jk}	R^2
US–Japan	84–91	-0.21 (-2.77) ^c	0.10	-0.19 (-2.67) ^c	0.11	-0.51 (-3.70) ^c	0.26
US–Germany	77–90	-0.85 (-10.44) ^c	0.10	-1.06 (-12.60) ^c	0.19	-0.94 (-11.37) ^c	0.07
US–UK	79–90	0.14 (3.33) ^d	0.03	-0.00 (-0.02)	0.02	-0.03 (-0.07)	0.03
US–France	78–90	-0.04 (-1.80)	0.01	-0.03 (-1.32)	0.02	-0.41 (-6.98) ^c	0.07
US–Italy	79–89	-0.36 (-6.94) ^c	0.08	-0.37 (-7.20) ^c	0.02	—	—
US–Canada	72–89	-0.14 (-9.66) ^c	0.10	-0.15 (-10.58) ^c	0.02	—	—
US–Australia	81–91	-0.19 (-1.45)	0.10	-0.44 (-2.96) ^c	0.04	—	—
US–Korea	72–90	0.32 (12.46) ^d	0.02	-0.12 (-5.60) ^c	0.01	-0.80 (-31.8) ^c	0.10
US–Mexico	80–90	-0.47 (-5.21) ^c	0.14	-0.29 (-3.83) ^c	0.10	-0.55 (-6.13) ^c	0.19

Note: $\log(X_{ijk}/M_{ijk}) = \alpha_{ijk4} + \beta_{jk4} \log c_{ijk-1} + \varepsilon_{ijk4}$ estimated by seemingly unrelated regressions. *t*-statistics in parentheses, based on heteroskedasticity-consistent (White) standard errors.

^a Log of the ratio of bilateral exports to bilateral imports.

^b Log of US relative to other unit labor cost.

^c The coefficient is significant at 1% level with the correct sign.

^d The coefficient is significant at 1% level with the incorrect sign.

mobility and technology transfer which have led to greater convergence of productivities across countries in recent decades.²¹

Productivity performs slightly better than unit labor costs when the dependent variable is relative exports, but the reverse is true when the dependent variable is bilateral trade balances. So there is no clear preference for either specification. The results suggest the importance of the choice of PPP conversion factor. For France and Korea, the results are particularly sensitive to the choice of PPP measure. The manufacturing-based disaggregated ICOP PPP measures yield the most successful results, but they are not available for many countries.

4. Conclusions

This paper provides fairly strong support for the Ricardian model, despite the serious difficulties involved in making the requisite international comparisons of productivity and labor compensation. In the vast majority of cases, relative productivity and unit labor cost help to explain US bilateral trade patterns, particularly when sector-specific purchasing-power-parity exchange rates are used. In most cases only a small part of the variation of trade patterns is explained by the model, but this is common in cross-sectional analysis. Despite its extreme simplicity, the Ricardian model continues to perform surprisingly well empirically.

References

- Balassa, Bela, "An Empirical Demonstration of Classical Comparative Cost Theory," *Review of Economics and Statistics* 4 (1963):231–8.
- Bardhan, Pranab, "Disparity in Wages But Not in Returns to Capital Between Rich and Poor Countries," *Journal of Development Economics* 49 (1996):257–70.
- Bhagwati, Jagdish, "The Pure Theory of International Trade: A Survey," *Economic Journal* 74 (1964):1–84.
- Bowen, Harry P., Edward E. Leamer, and Leo Sveikauskas, "Multicountry, Multifactor Tests of the Factor Abundance Theory," *American Economic Review* 77 (1987):791–809.
- Caves, Richard et al. (eds.), *Industrial Efficiency in Six Nations*, Cambridge, MA: MIT Press (1992).
- Caves, Richard E., Jeffrey A. Frankel and Ronald W. Jones, *World Trade and Payments*, 7th edn, New York: HarperCollins (1996).
- Davis, Donald R., "Intra-Industry Trade: A Heckscher–Ohlin–Ricardo Approach," *Journal of International Economics* 39 (1995):201–26.
- Deardorff, Alan, "Testing Trade Theories and Predicting Trade Flows," in Ronald W. Jones and Peter B. Kenen (eds.), *Handbook of International Economics*, Vol. I, Amsterdam: North-Holland (1984):467–517.
- Dollar, David and Edward N. Wolff, *Competitiveness, Convergence, and International Specialization*, Cambridge, MA: MIT Press (1993).
- Ethier, Wilfred, *Modern International Economics*, 3rd edn., New York: Norton (1995).
- Ferguson, D. G., "International Capital Mobility and Comparative Advantage: The Two-Country, Two-Factor Case," *Journal of International Economics* 8 (1978):373–96.
- Gagnon, Joseph E. and Andrew K. Rose, "Dynamic Persistence of Industry Trade Balances: How Persistent is the Product Cycle?" *Oxford Economic Papers* 47 (1995):229–48.
- Giovannini, Alberto, "Exchange Rates and Traded Goods Prices," *Journal of International Economics* 24 (1988):45–68.
- Golub, Stephen S., "Comparative Advantage, Exchange Rates, and Sectoral Trade Balances of Major Industrial Countries," *IMF Staff Papers* 41 (1994):286–313.
- Hooper, Peter M. and Kathryn A. Larin, "International Comparisons of Labor Costs in Manufacturing," *Review of Income and Wealth* 35 (1989):335–55.
- Hooper, Peter M. and Elizabeth Vrankovich, "International Comparisons of the Levels of Labor Costs in Manufacturing," in Keith E. Maskus, Peter M. Hooper, Edward E. Leamer, and J. David Richardson (eds.), *Quiet Pioneering: Robert M. Stern and His International Economic Legacy*, Ann Arbor: University of Michigan Press (1997):231–82.
- Isard, Peter, "How Far Can We Push the Law of One Price?" *American Economic Review* 67 (1977):942–8.
- Jones, Ronald W., "Comparative Advantage and the Theory of Tariffs: A Multi-Country, Multi-Commodity Model," *Review of Economic Studies* 28 (1961):161–75.
- , "Comparative and Absolute Advantage," *Swiss Journal of Economics and Statistics* 3 (1980):235–60.
- Jorgenson, Dale W., *Productivity, Vol. 2: International Comparisons of Economic Growth*, Cambridge, MA: MIT Press (1995).
- Jorgenson, Dale W. and Masahiro Kuroda, "Productivity and International Competitiveness in Japan and the United States, 1960–1985," in Charles R. Hulten (ed.), *Productivity Growth in Japan and the United States*, Chicago: University of Chicago Press (1990):29–55.
- Krugman, Paul R., "Intraindustrial Specialization and the Gains from Trade," *Journal of Political Economy* 89 (1981):959–74.
- Krugman, Paul R. and Maurice Obstfeld, *International Economics: Theory and Policy*, 4th edn., Reading MA: Addison-Wesley (1997).
- Leamer, Edward E. and James Levinsohn, "International Trade Theory: The Evidence," *Handbook of International Economics*, Vol. 3, Amsterdam: North-Holland (1996).
- MacDougall, G.D.A., "British and American Export: A Study Suggested by the Theory of Comparative Costs, Part I," *Economic Journal* 61 (1951):697–724.

- McKinsey Global Institute, *Manufacturing Productivity*, Washington: McKinsey (1993).
- Maddison, Angus and Bart Van Ark, "The International Comparison of Real Product and Productivity," University of Groningen Research Memorandum 567 (GD-6) (1994).
- Maskus, Keith E., "Comparing International Trade Data and Product and National Characteristics Data for the Analysis of Trade Models," in Peter Hooper and J. David Richardson (eds.), *International Economic Transactions: Issues in Measurement and Empirical Research*, Chicago: University of Chicago Press (1991):17–56.
- Noussair, Charles N., Charles R. Platt, and Raymond G. Riezman, "An Experimental Investigation of the Patterns of International Trade," *American Economic Review* 85 (1995):462–91.
- Petri, Peter, "A Ricardian Model of Market Sharing," *Journal of International Economics* 10 (1980):201–11.
- Romer, Paul M., "Endogenous Technological Change," *Journal of Political Economy* 98 (1990):S71–102.
- Stern, Robert M., "British and American Productivity and Comparative Costs in International Trade," *Oxford Economic Papers* 14 (1962):275–303.
- Trefler, Daniel, "International Factor Price Differences: Leontief Was Right," *Journal of Political Economy* 101 (1993):961–87.
- , "The Case of the Missing Trade and Other Mysteries," *American Economic Review* 85 (1995):1029–46.
- Van Ark, Bart and Dirk Pilat, "Productivity Levels in Germany, Japan and the United States: Differences and Causes," *Brookings Papers on Economic Activity Microeconomics* (1993):1–48.
- Wolff, Edward N., "Productivity Growth and Capital Intensity on the Sector and Industry Level: Specialization Among OECD Countries, 1970–1988," mimeo, New York University (February 1993).
- World Bank, *Purchasing Power of Currencies* (with *Stars* diskettes), International Economics Department (1993).

Notes

1. For example, Krugman and Obstfeld (1997, pp. 32–3) discuss Balassa's findings, while Ethier (1995, pp. 20–3) discusses MacDougall's results.
2. The same analysis applies when the number of countries is different from the number of goods. The symmetric case is used for simplicity of exposition, as in Jones (1961).
3. In Krugman's model, specific factor endowments drive interindustry trade, but the model can be amended easily to include differences in technology.
4. The failure of wage rates to converge across countries despite high and rising international capital mobility is something of a puzzle. See Bardhan (1996) for a discussion of this puzzle and possible explanations.
5. See also Caves et al. (1996, section 9.4).
6. Dollar and Wolff (1993, ch. 7) is a partial exception, but their focus is more on convergence of trade patterns across countries than explaining the sectoral pattern of trade. Golub (1994) used a Ricardian framework to analyze sectoral trade for the seven major industrial countries, but the focus there was mostly on time series, whereas in this paper we have a much richer cross-sectional dataset.
7. See section 3 and an unpublished appendix available from the authors for a description of the sources and methods of computing sectoral productivity in this paper. Note that these measures of productivity do not adjust for hours worked. Since hours are longer in Japan and shorter in Germany than in the United States, such an adjustment would lower Japanese productivity and raise German productivity.
8. See Bowen et al. (1987), for example. Trefler (1993, 1995) claims that the inclusion of neutral technological progress greatly improves the performance of the neoclassical model, but his evidence is indirect, since he does not directly measure differences in technology, but assumes them.

9. The OECD STAN database provides data for most OECD countries, including Mexico and South Korea, on most of the variables needed to perform the tests. For 49 sectors, the STAN database includes: exports and imports, value added by sector (in current and constant prices), number of persons engaged, and total national-accounts-compatible labor compensation, 1970–93. Thus, we are able to calculate labor productivity (real value added per person engaged), compensation per employee, and unit labor costs for each of the sectors, and relate the latter to trade flows. Details on sources and methods are available from the authors on request.
10. Another advantage of including bilateral trade is that we are able to use the full 49-sector STAN sample. The BTD, our source for bilateral trade data, disaggregates into only 26 sectors.
11. Bilateral trade of Korea and Mexico with OECD countries is available in BTD at the 26-sector level, but total Korean and Mexican exports and imports are not available.
12. Bhagwati (1964) objected to the lack of theoretical justification for the use of export ratios.
13. Balassa also considered relative wages but found that this added little explanatory power, with wages having the wrong sign. MacDougall examined relative unit labor costs for a subset of his sample.
14. See Hooper and Vrankovich (1997) for a detailed discussion of this issue. See also Hooper and Larin (1989) and Maskus (1991).
15. The best-known and most widely used PPPs are the expenditure PPPs (EPPPs) for disaggregated components of expenditure on gross domestic product produced by the Heston–Summers International Comparison Project (ICP). These EPPPs are now available for a wide range of countries and at a high level of disaggregation (World Bank, 1993). Unfortunately, however, these EPPPs are not ideal for measuring differences in output prices, owing to differences between expenditure and output prices by sector. One remedy, recently implemented by Jorgenson and Kuroda (1990) and Hooper and Vrankovich (1997), is to adjust EPPPs for at least some of these various factors. This is a difficult undertaking at a disaggregated level, and efforts so far have been limited to the major industrial countries. An alternative output-based approach involves computation of unit-value ratios by dividing the value of output by the quantities produced at a highly disaggregated level. This approach has been adopted recently by the International Comparison of Output and Productivity (ICOP) at the University of Groningen (see Maddison and van Ark (1994) for a survey). ICOP has generated detailed manufacturing PPPs for about 15 countries. For the purposes of comparing manufacturing productivity, the ICOP measures seem preferable to the unadjusted EPPPs from ICP, but they have significant disadvantages too. Further details are available in an appendix available from the authors on request.
16. Gagnon and Rose (1995) demonstrate the strong persistence of the pattern of bilateral trade balances even for highly disaggregated trade data.
17. We also estimated the equations allowing the coefficient on relative unit labor costs to vary across years. For every country pair, we were not able to reject the null that the coefficients are the same over years. Thus, in the results presented below, we constrain the coefficient on unit labor cost to be equal over time.
18. The R^2 is estimated for each year based on the constrained SUR fitted equation for all years, which is part of the reason for the low values. But the R^2 are also quite low for individual year OLS regressions in most cases.
19. Balassa's R^2 range from 0.6 to 0.8 depending on the specification of the equation. Stern's R^2 vary from 0.4 to 0.5.
20. When the independent variable is contemporaneous rather than lagged, Italy also has the wrong sign. On the other hand, the results for Australia, France, and the UK are better when the independent variable is contemporaneous.
21. Dollar and Wolff (1993) document this tendency towards convergence of productivity, although they find that it is less pronounced at the sectoral level than at the aggregate level.