East is east and west is west: a ricardian-heckscher-ohlin model of comparative a...

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Morrow The University of Toronto January 8th, 2008 Abstract Models of comparative advantage are usually based either on di? erences in factor abundance or di? erences in total factor productivity within a country despite considerable empirical evidence that both matter. This paper articulates a uni? ed and tractable model in which comparative advantage exists due to di? erences in factor abundance and relative productivity di? erences across a continuum of industries with monopolistic competition and increasing returns to scale. I provide evidence that both sources of comparative advantage shape international production patterns.

In addition, I ? nd that relative productivity di? erences across industries are uncorrelated with the factor intensities of these industries. Therefore, each of the two forces for comparative advantage o? ers valid partial descriptions of the data. Consequently, simply aggregating the predictions of the factor abundance-based and relative productivity-based models can be used to obtain a full description of industry-by-industry production patterns. I thank Mary Amiti, Olivier Coibion, Alan Deardor? , Ann Ferris, Yuriy Gorodnichenko, Juan Carlos Hallak, James Levinsohn, Jagadeesh Sivadasan, Gary Solon, and

Daniel Tre? r. I also thank seminar participants at Columbia University, The Federal Reserve Bank of New York, the University of Michigan, Syracuse University, and The University of Toronto. All errors are mine and mine alone. The title of this paper comes from the poem “ The Ballad of East and West” by Rudyard Kipling which begins “ Oh, East is East, and West is West, and never the twain shall meet…. ” 1 1 Introduction Production patterns around the world exhibit tremendous heterogeneity and specialization. For example, the United States supplies 16. 2% of the world’s exports of aircraft while China provides only 0. %. On the other hand, China supplies 14. 9% of the world’s export supply of apparel and clothing while the United States only supplies 0. 9%. 1 The Ricardian and Heckscher-Ohlin (HO) theories are the two workhorse models used to explain this specialization. The Ricardian model of international trade predicts that countries specialize in goods in which they hold the greatest relative advantage in total factor productivity (TFP). 2 The Heckscher-Ohlin model ignores di? erences in TFP across industries and assumes that all countries possess the same production function in a given industry.

Heckscher-Ohlin asserts that di? erences in comparative advantage come from di? erences in factor abundance and in the factor intensity of goods. Neither model, in isolation, o? ers a complete description of why production patterns di? er nor does either o? er a uni? ed theory of international specialization. Consequently, empirical tests of each model can be subject to the omitted variable problems associated with ignoring the other. Finally, little work has been done in assessing the relative empirical importance of the two models. This paper presents a uni? d structural framework that nests each source of comparative advantage when there is a continuum of industries. The model’s tractability allows me to estimate the relative contributions of Ricardian and HO forces through traditional estimation techniques. I highlight three important ? ndings. First, both the Ricardian and HO models possess robust explanatory power in determining international patterns of production. Second, the two models are empirically separable in my broad sample in that the forces that determine comparative advantage in one model are orthogonal to the forces that determine comparative advantage in the other model.

Finally, I ? nd that a one standard deviation change in relative factor abundance is approximately twice as potent as a? ecting change in the industrial structure of an economy as a one standard deviation change in industry-speci? c relative TFP. Although the ? rst result has been documented Data taken from “ World Trade Flows” bilateral trade data compiled by Robert Feenstra et al. (2005) for the year 1990. Aircraft is SITC code 792 and Clothing and Apparel is SITC code 84. 2 The original “ Ricardian” model only focused on di? rences in opportunity cost across industries and did not explore from where these di? erences came. For the entirety of this paper, I take “ Ricardian” technology di? erences to be di? erences in TFP as in Dornbusch, Fischer, and Samuelson (DFS) (1977). 1 2 in past reduced form estimation, this is the ? rst to do so based on a uni? ed structural model. The second and third results are new and provide substantial insight into how we can integrate these two important approaches. More technically, I articulate a uni? ed and tractable model in which comparative advantage exists due to di? rences in factor abundance and/or relative productivity di? erences across a continuum of monopolistically competitive industries with increasing returns to scale. In this manner, I rely on the quasi-Heckscher-Ohlin market structure of Romalis (2004) while augmenting his model with Ricardian TFP di? erences. By developing a tractable model that possesses theoretically meaningful nested hypotheses, I am able to dissect patterns of comparative advantage into those driven by Ricardian forces and those driven by HO. In addition, I derive conditions under which tests of the HO model will not su? r from an omitted variable bias in ignoring Ricardian TFP di? erences. This uni? ed model allows me to nest the precise alternate hypothesis that a country that possesses a relative abundance of a factor also possess levels of relative TFP that are systematically higher (or lower) in industries that use this factor relatively intensively. In trying to explain patterns of skill-biased-technical-change, Acemoglu (1998) suggests that skilled labor abundant countries will have higher levels of relative TFP in skilled-labor intensive industries than in unskilled labor intensive industries. If the mechanisms in his model are pervasive in the data, economists will tend to confound the two models when one is tested without the other as a meaningful alternate hypothesis. 4 Empirically, Kahn and Lim (1998) ? nd that TFP in the United States in the 1970s increased far more in skill-intensive industries than in industries that use unskilled labor relatively intensively. On the other side, if Ricardian TFP di? erences in? uence production patterns in a manner that is inconsistent with HO, this might suggest why HO results sometimes appear to be unstable. After solving the model, I estimate it using panel data across 20 developed and developing countries, 24 manufacturing industries and 11 years (1985-1995). I highlight three major ? ndings. First, I ? nd that both productivity di? erences and the interaction of factor abundance with factor 3

However, he also shows that all predictions about relative TFP across sectors depend crucially on the enforcement of Northern property rights of technology in the South. This possibility has also been the subject of conjecture by authors such as Fitzgerald and Hallak (2004) although the modeling techniques have not existed for empirically examining this possibility. 5 e. g. Bowen, Leamer and Sveikauskas (1987) 3 intensity play a role in determining international specialization patterns. Second, there is very little evidence that relative productivity is systematically correlated with factor intensity. This suggests that productivity levels that are non-neutral across industries have little in? uence on whether results consistent with HO appear in the data.

Third, I ? nd that a one standard deviation increase in relative factor abundance is 1. 6 to 2. 3 times as potent in a? ecting change in the commodity structure of the economy as a one standard deviation change in Ricardian productivity. This suggests that di? erences in factor abundance are more potent than di? erences in Ricardian productivity in determining patterns of specialization. The key to nesting the Ricardian alternate hypotheses is decomposing industry-level TFP differences into three components: country-level TFP that di? rs across countries but is identical across industries within any given country, productivity that is correlated with factor intensity and is purged of country averages, and productivity that varies across industries but is orthogonal to factor intensity and is purged of country averages. If productivity is correlated with factor intensity, the two models can be confounded easily and tests of a single model will typically su? er from omitted variable bias. If TFP is orthogonal to factor intensity, it is reasonable to model TFP as consisting of a country-speci? term that is neutral across industries and an idiosyncratic component that is orthogonal to factor intensity. Empirically, when TFP is uncorrelated with factor intensity, HO is valid as a partial description of the data. Consequently, common tests of and the standard comparative statics associated with the HO model are valid (e. g. Rybczynski regressions) because Ricardian TFP predictions are not correlated with the factor intensity di? erences across goods that are the foundation of most of these empirical tests. However, industry-by-industry level predictions must take Ricardian di? rences into account. For example, the change in the commodity structure resulting from a change in number of skilled workers in a country can be estimated from a HO model but the level of production accruing to a certain industry must take HO and Ricardian considerations into account. Examining if relative TFP is correlated with factor intensity in other data sets will suggest if this orthogonality assumption is valid in other work. This paper is related to two strands of literature on the empirical determinants of specialization 4 and trade. The ? rst strand documents the in? ence of Ricardian TFP on international production patterns. MacDougall (1951, 1952) ? nds early evidence of the Ricardian model using data from the United Kingdom and the United States. Costinot and Komunjer (2007) augment the model of Eaton and Kortum (2002) to include industries and ? nd that relative value added per worker possesses predictive power in determining patterns of industrial specialization in a broad panel of countries. The second related strand of literature documents the importance of factor abundance in determining country and industry level trade patterns.

Early empirical investigations of the in? uence of factor abundance on production patterns include Leontief (1954) and Baldwin (1971). 6 More recently, Tre? er (1995), Davis and Weinstein (1999), Debaere (2003) and Romalis (2004) document patterns of trade consistent with HO. Based on these two strands of literature, there is broad agreement that both the Ricardian and HO models are important for understanding international patterns of production. Consequently, there is a need for a uni? ed framework that can address the relative importance of these two forces as well as their potential interaction.

Harrigan (1997) and Harrigan and Zakarasjek (2001) examine the contributions of TFP and factor abundance in determining specialization in a series of industry level studies that rely on reduced-form estimation based on translog approximations to the revenue function. Although they do not explicitly model the interaction of TFP and factor abundance in general equilibrium, these are the closest empirical antecedents to this paper. In addition, they do not examine when the omission of Ricardian technology introduces systematic biases in tests of the HO model. This paper is less related to Tre? r (1993) who shows that taking country-level di? erences in TFP into account improves the performance of Heckscher-Ohlin-Vanek models by allowing for better measurement of factor abundance. Theoretical antecedents of this paper include Findlay and Grubert (1959) who were among the ? rst to use a two country, two good, two factor model to consider the e? ects of Ricardian productivity and factor abundance in jointly determining factor prices and production patterns. Xu (2001) works out a complete set of results regarding how technological progress impacts relative factor prices in a two country, two industry, two factor model.

Bernard, Schott and Redding (2006) For thorough surveys of empirical tests of theories of trade, see Deardor? (1985) and Leamer and Levinsohn (1995). 6 5 use Melitz's (2003) model of ? rm heterogeneity to derive results consistent with the HO theorem. Although it provides substantial theoretical insights, their model requires data that is disaggregated to a level that is not available in international data sets that possess broad coverage. 7 The paper is organized as follows. Section II sketches a simple two industry, two country, two factor version of the model.

Section III extends the simple model to a continuum of industries and derives the empirically testable form. Section IV describes the data and the construction of the TFP measures used in the paper. Section V presents the baseline results. Section VI presents robustness tests, and Section VII concludes. 2 Theory: A Simple 2x2x2 Model I ? rst work through a simple two country, two factor, two industry model to illustrate the essence of a more general model. My model augments the quasi-Heckscher-Ohlin structure of Romalis (2004) with Ricardian TFP di? erences.

This simple model solves for equilibrium factor prices and production as functions of exogenous factor abundance and productivity using two equilibrium conditions to extract the separate contributions of productivity and factor abundance on relative production patterns across industries in a country. I focus on the case where both countries produce in each industry such that intra-industry trade exists. I start by deriving a goods market clearing condition that maps relative factor prices to relative production values of goods demanded from skilled and unskilled labor intensive industries.

I close the model by deriving a factor market clearing condition that assures full employment for both factors. I then show how Ricardian productivity di? erences can introduce substantial biases in empirical tests of the HO model. 2. 1 Production This section presents the supply side of the model including the production function and the pricing behavior of a ? rm. The two factors of production are skilled labor (S) and unskilled labor (U). The wages of these two factors are represented by ws and wu , respectively. Let ? ? 7 ws wu . For simplicity, In addition, their model focuses on the case where ? ms take productivity draws from the same distribution across industries. Consequently, all di? erences in average TFP within a industry across countries are endogenous responses to exogenous di? erences in factor abundance. 6 de? ne the two countries as the North and the South. All Southern values possess asterisks. Although this is relaxed completely in the more general model, assume for the moment that aggregate incomes in the two countries are identical (Y = Y ?). The two industries are indexed by their Cobb-Douglas skilled labor factor cost shares, z, where z= ws S(z) ws S(z) +wu U (z) and $0 < z < 1$. s is the skilled labor factor cost share of the skilled labor intensive good and zu is the skilled labor factor cost share of the unskilled labor intensive good. Consequently, z is both a parameter and the index of industries. Without loss of generality, assume that zs > zu . Firms within each of the two industries each produce unique and imperfectly substitutable varieties. Hicks neutral TFP (A(z)) augments skilled and unskilled labor in production of a ? nal good x(z) z 1? z and coverage of ? xed costs f (z)ws wu such that total cost for a given Northern ? rm i in industry z takes the following form: z 1? z ws wu . z (1 ? z)1? z A(z) T C(z, i) = [x(z, i) + f (z)] (1) As is common in the literature, I assume that skilled and unskilled labor are used in the same proportion in ? xed costs as in marginal costs. Previewing the demand structure, prices are a constant markup over the Cobb-Douglas marginal cost. The markup is equal to and 1 1?? 1 ? where 0 < ? < 1 is the elasticity of substitution between varieties within an industry. A zero pro? t condition ? f (z) 1?? . solves for output per ? rm, x(z) = As is common in this class of model, all di? erences in international production patterns occur at the extensive margin as output per ? m is pinned down by exogenous parameters. Assume that the elasticity of substitution and ? xed costs are the same in the two countries for a given industry so that output per ? rm is constant across countries within an industry. I further assume that all ? rms within an industry and country have access to the same production function and face the same factor prices. Therefore, for a given industry z, the price of a Northern good relative to its Southern equivalent can be expressed as follows where Northern relative to Southern values are denoted with tildes: ws wu ? z ? 1? z ? wu ? ? = . ? ? A(z) A(z) p(z) = ? (2) 7 The following notation introduces Ricardian productivity di? erences: ? A(zs) = ?? ? ? A(zu) A(zs) A(zu) A? (zs) A? (zu) (3) If ? > 1, the North is relatively more productive in the skill intensive industry than the unskilled ? intensive industry. If ? < 1, the North is relatively more productive in the unskilled labor intensive ? industry. If ? = 1, the North is equally relatively productive in the two industries. ? 2. 2 Demand This section links prices to consumption patterns. Demand is based on a two tier utility function.

Consumers in each of the two countries have utility (?) that is Cobb-Douglas over the two industries but CES across varieties within each of the industries. Although it will be loosened in the more general section, assume for the moment that expenditure share for each industry is constant and equal to 0. 5. For a given industry z, n(z) is the endogenously determined number of Northern ? rms and n? (z) is the number of Southern ? rms and the total number of varieties/? rms in a given industry is N (z) = n(z) + n? (z) where i indexes varieties/? rms within industry z. ? = C(zs)0. 5 C(zu)0. 5

N (zk) 1 ? (4) C(zk) = 0 x(zk , i) di ? k ? S, U (5) Consumers buying from a foreign ? rm incur iceberg transportation costs ? > 1 such that if the price of a domestically produced good is p(z) then the price of the same good abroad is ? p(z). Revenue accruing to a ? rm in the North is equal to its receipts from domestic and foreign consumers. Appendix A shows how Northern and Southern ? rms' revenue functions can be used to solve for the number of Northern ? rms relative to the number of Southern ? rms in a given industry as Romalis (2004): ? 2(1??) + 1 ? 2? 1?? p? ? . 2(1??) + 1) ? 2? 1?? 1?? p(? ? p n(z) n? (z) n= ? (6) 8 Because output per ? rm is pinned down, aggregate Northern revenue relative to aggregate Southern revenue in industry z is: ? 2(1??) + 1 ? 2? 1?? p? ? n(z)p(z)x(z) = 2(1??) . ? (z)p? (z)x? (z) 1?? p?? n ? + 1 ? 2? ? ? R(z) = (7) ? I restrict my attention to the case where R(z) > 0 such that both the North and South produce in a given industry. 8 Romalis (2004) provides restrictions on p(z) that give necessary and su? cient ? ? conditions for R(z) > 0. Because ? rms produce on the elastic portion of their demand curve, ? ? R ? p ? < 0. 9 As a country's elative price goes up its relative revenue in that industry falls. Finally, it is straightforward to show that the share of production in industry z accruing to the North is also decreasing in p(z) where ? the share is de? ned as v(z) = R(z) R(z)+R? (z) = ? R(z) . ? R(z) +1 2. 3 Equilibrium To solve for equilibrium production patterns and factor prices, I introduce price di? erences coming from Heckscher-Ohlin and Ricardian forces. To solve for the equilibrium, I start by deriving the goods market clearing condition. Starting with the simple case where comparative advantage only comes from di? rences in factor abundance, I show that if ? ? > ? then v(zs) v(zu) > v ? (zs) v ? (zu) . That is, the relative value of goods demanded in an industry will be declining in the relative wage of the factor that is used relatively intensively in that industry. Appendix B derives this rigorously. As in Romalis (2004), factor price equalization fails due to transportation costs. This relationship is shown by the line DD in Figure 1 which depicts the goods market clearing condition. A factor market clearing condition closes the model. De? ne world income as Y w = Y + Y ? Based on CobbDouglas production, the ratio of aggregate payments to skilled labor relative to those to unskilled 8 The intuition for the model is unchanged when allowing for specialization although solving for equilibrium production patterns becomes more complex. 9 As Romalis (2004) notes, as ? > ? and ? = 1 the model becomes one of perfect competition as in DFS (1977) for the case of comparative advantage from Ricardian productivity and DFS (1980) for the HO case. With transportation costs and perfect competition, there are non-traded goods and no intra-industry trade.

With monopolistic competition but no transportation costs, FPE results as long as factor endowments are not too dissimilar, the location of production becomes indeterminate for a given industry and we cannot make industry-by-industry predictions. Romalis (2004) ? also contains a proof that ? R < 0. ? p ? 9 labor is 0. 5 k? s, u v(zk)zk Y w ws S S = =? . 0. 5 k? s, u v(zk)(1 ? zk)Y w wu U U Simple manipulation gives zu + (1 ? zu) + v(zs) v(zu) zs v(zs) v(zu) (1 (8) ? zs) =? S . U S U (9) = 0 gives the following Taking a total derivative of the above expression and setting d expression v(zs) S = ? V = d? v(zu) U z s ? zu 1 ? zu + v(zs) v(zu) (1 ? d where ? = (10) ? zs) 2 > 0. (11) Because zs > zu , K > 0 and the relative wage of the factor used relatively intensively in an industry will increase as productive factors are reallocated to that industry. This is the factor market clearing condition FF. Examining Figure 1, if F N F N is the factor market clearing condition for the Northern country, the Southern factor market clearing condition F S F S is below and to the right of F N F N . The location of F S F S relative to F N F N is given by solving for 8. Figure 1 con? ms the intuition of the simplest HO model. The North possesses a relative abundance of skilled labor and its relative wage of skilled labor is less than in the South. Consequently, the North produces relatively more of the skill intensive good. The South produces relatively more of the unskilled labor intensive good. I can also use this framework to illustrate a simple Ricardian model in Figure 2. Suppose that the North produces relatively more of the skill intensive good due to Ricardian TFP di? erences and possesses the same factor endowments as the South. If the North is systematically more productive d?

S dU using equation 10 Figure 1: Equilibrium: Heckscher-Ohlin Model Figure 2: Equilibrium: Ricardian Model 11 Figure 3: Hybrid Model in the skill intensive industry, its goods market clearing condition DN DN will be above and to the right of the goods market clearing condition for the South, DS DS .

This is because the North generates higher demand at a given set of factor prices than the South in the skill intensive industry because it possesses relatively higher TFP in that industry. Because factor endowments are the same in each country, they share a common factor market clearing condition, F F .

The North produces relatively more of the skill intensive good and the relative wage of skilled labor is bid up as resources are reallocated to the skill intensive industry. Finally, consider a hybrid of the two models where Northern industry TFP is positively correlated with the skilled labor intensity of goods and the North possesses a relative abundance of skilled labor. This hybrid model is portrayed in Figure 3. If we only observe di? erences in V and V ? and di? erences in factor abundance, we will confound the e? cts of high relative productivity and factor abundance when performing tests of HO because we cannot distinguish shifts in the F F curve from shifts in the DD curve. In this example, omitting productivity from empirical work when factor prices are unobserved will result in a substantial omitted variable bias in interpreting HO tests because the cumulative e? ect of factor abundance and productivity will be attributed to factor abundance. 12 If relative TFP is negatively correlated with skill intensity in the skill abundant country, the HO prediction is less likely to appear in the data (e. g. he North produces a lower V than if productivity was distributed identically across industries). In the ? rst case, the uni? ed RicardianHO model provides a meaningful alternate hypothesis for a given set of production patterns and a solution to an omitted variable bias. In the second case, it allows for the possibility that HO predictions can be rescued. Finally, if TFP is uncorrelated with factor intensity, we will not expect it to a? ect HO predictions at all. 3 Theory: A Continuum of Industries I now generalize my analysis to a continuum of industries as in Dornbusch, Fischer, and Samuelson (1980) and Romalis (2004).

I also derive estimable expressions for gauging the presence of Ricardian productivity and HO forces in determining international patterns of production. Industries with higher values of z use a more skill intensive production technique at a given set of factor prices than those with a lower z. With a continuum of industries, ? rst tier utility (?) takes the form: 1 ?= 0 b(z)ln[C(z)]dz, (12) b(z) is the exogenous Cobb-Douglas share of expenditures associated with each industry. The consumption aggregator for each industry, C(z), is the same as in the simple model. I abandon the restriction that Y = Y ? nd de? ne the relative value of production between the two countries as ? ? 2(1??) Y + 1 ? ? 1?? p(z)? (Y + 1) n(z)p(z)x(z) Y . = 2(1??) Y Y ? ?? ? 1?? (Y ? + 1) n(z)? p(z)? x(z)? ? + Y ? p(z) ? Y ? ? ? p R(? (z)) = (13) As before, I am particularly interested in the case where intra-industry trade occurs such that ? p ? R(? (z)) > 0. De? ne r(z) = ln R(z) and take a total derivative of this expression with respect to ? ln (? (z)) to obtain the following expression: p d? (? (z)) = ? (?)d ln(? (z)), r p p p ?(?) < 0 p (14) 13 where10 ??? 1?? ?(? (z)) = p Y? Y +1 p(z)? 2(1??) + ? p(z) ? 2(1??) + ? Y? Y Y? Y ? 2? 1?? Y? Y + 1 + p(z)?? ? 2(1??) Y + 1 ? Y Y? Y ? ? p(z)?? ? 1?? ? +1 2 < 0. (15) Relative prices re? ect di? erences in comparative advantage that come from TFP di? erences and di? erences in factor prices wu ? ? A(z) p(z) = ? z ? ? (16) For a given set of relative factor prices, comparative advantage can emerge both because of the interaction of relative factor prices and factor intensity (? z) or because of relative di? erences in ? ? TFP, A(z). Because I need to keep track of productivity in many industries, I use a convenient ? arameterization of productivity as follows where a(z) = ln A(z) ? a(z) = a + ln (?) z + ? A(z) ; ? ? ? ln(?) = ? 2 ? A(z) i. i. d. (0, ? A(z)), ? (17) (18) cov[z, a(z)] ? . var(z) This conveniently breaks TFP into three components: country level di? erences that are neutral across industries (?), di? erences across industries that are correlated with factor intensity (ln(?)z), a ? and di? erences across industries that are orthogonal to factor intensity (? A(z)). Country level di? erences in relative productivity pose the fewest problems for HO theory in that they can easily be modeled as an increase in country size. 1 The component of Ricardian TFP that is correlated with factor intensity is captured by ln(?)z. ln(?) is just the ordinary least squares (OLS) coe? cient ? ? of a regression of a(z) on skill intensity (z) under normal OLS assumptions. This poses problems for ? HO theory because it o? ers a well articulated alternate hypothesis for why we ? nd HO production patterns in data. If ? > 1, then cov[z, a(z)] is positive and skilled labor intensive industries will on average ? ? 10 11 Recall that this derivative is negative when ? > 1 and iceberg transportation costs exist.

See Dornbusch, Fischer, and Samuelson (1980) for the simplest example of this. 14 have higher TFP than unskilled labor intensive industries. If ? < 1, then cov[z, a(z)] is negative ? ? and skilled labor intensive industries on average have lower TFP than unskilled labor intensive industries. If ? = 1, then cov[z, a(z)] = 0 and productivity is uncorrelated with skill intensity. ? ? TFP that is uncorrelated with factor intensity and purged of country level e? ects is represented by ? A(z) . Because this component of TFP is orthogonal to factor intensity and purged of country e? cts by assumption, it is part of a model that is separable from HO forces. Consequently, if TFP is uncorrelated with factor intensity, aggregate predictions can be made by simply aggregating the predictions of the two models. I exploit the monotonic relationship between v(z) and ln(? (z)) and take a ? rst order linear p approximation around the skill labor intensity z0 . Using the implicit function theorem, I can simplify v(z) as a linear function of z. p ? v(z0) ? ln(? (z0)) (z ? z0) ? ln(? (z0)) p ? z0 ? R(z0) ? 1 + R(z0) 2 ? (z0) ln v(z) = v(z0) + (19) v(z) = v(z0) + ? (z ? z0) ? ? (20) ? R(z0) 2 ? (z0) ? [1+R(z0)] Solving for the covariance of v(z) with z gives the simple expression where ? (z0) = 0 cov[z, v(z)] = ? (z0) ln ? ? var(z) ? ? < (21) This expression is the continuum of industries analog of the goods market clearing condition DD from the two industry model. Although applicable to any two factors of production, this expression shows how a given correlation between skill intensity and production can occur for two reasons. First, if productivity is uncorrelated with factor intensity (? = 1), relatively cheap skilled ? abor (? < 1) can lead countries to produce more skilled labor intensive goods (cov[v(z), z] > 0). 12 ? Second, even if factor prices do not di? er (? = 1) production can be skewed towards skill intensive ? industries (cov[v(z), z] > 0) because productivity is systematically higher in skilled labor intensive industries (? > 1). ? 12 Recall that ? < 0. 15 I now present the continuum of industries analog of the factor market clearing condition. The following equations are the factor market clearing conditions for the North in skilled and unskilled labor, 1 0 1 0 (z)v(z)zY w dz = ws S, (22) (23) b(z)v(z)(1 ? z)Y w dz = wu U. Dividing equation (22) by (23) gives 1 0 b(z)zv(z)dz 1 0 b(z)(1 ? z)v(z)dz = ws S . wu U 1 0 b(z)dz (24) = 1 and interpret b(z) as a I exploit the fact that b(z) is everywhere non-negative and sample probability density. Therefore, the expressions can be rewritten using sample expectations. A Southern factor market clearing condition follows analogously so that the two factor market clearing conditions are: E[zv(z)] ws S = E[(1 ? z)v(z)] wu U ? E[z(1 ? v(z))] ws S ? = ? ?. E[(1 ? z)(1 ? v(z))] wu U (25) (26)

Taking the ratio of these two expressions and simplifying gives the following factor market clearing condition: ? g + cov[v(z), z] S =? ? ? g U where g = E[z]E[v(z)] ? E[v(z)]E[v(z)z] ? E[z]E[v(z)z] + [E(v(z)z)]2 . 13 (28) (27) Proposition 1 states that when Ricardian productivity di? erences are uncorrelated with factor inNote that because it was derived from expectations of a product of strictly positive terms, both the numerator and denominator must be strictly positive. 13 16 tensity, HO forces should be present and should contribute to the relative production structures of the two countries. . 1 Su? cient Conditions for “ separability” between HO and Ricardian models. Proposition 1: If productivity is uncorrelated with factor intensity and the relative abundance of factors di? ers among countries, then the relative wage of a country’s abundant factor will be less than in the country where it is a relatively scarce factor. In addition, cov[v(z), z] > 0 where z is the Cobb-Douglas cost share of its relatively abundant factor and cov[v(z), z] < 0 where z is the Cobb-Douglas cost share of its relatively scarce factor.

Proof : See Appendix This proposition is important because it shows that if TFP is uncorrelated with factor intensity, then basic HO results should hold in the data. Intuitively, when relative TFP is uncorrelated with factor intensity, di? erences in TFP across industries will not cause (or prevent) empirical tests of Heckscher-Ohlin to ? nd evidence of factor abundance based production and trade. Consequently, the e? ect of changes on the production structure coming from di? erences in factor abundance (i. e. Rybczynski regressions) or the net exporting position of a given factor (e. . HOV tests) are unlikely to be a? ected by di? erences in relative TFP across industries if TFP is uncorrelated with factor intensity. When TFP is correlated with factor intensity, any reduced form relationship between factor intensity, factor abundance and production will likely be due to both factor abundance and Ricardian TFP. It is also possible that relative Ricardian TFP di? erences will be large enough that a country that possesses a relative abundance of a factor will not produce relatively more of the good that uses that factor relatively intensively.

For example, the South might have TFP that is systematically high enough in skill intensive industries that it will produce relatively more skilled labor intensive goods than the North. Intuitively, this is most likely to occur when di? erences in factor abundance are very small and/or di? erences in ? are very large. I now derive an empirically testable model that nests the separate contributions of Ricardian and HO forces to production patterns. 17 3. 2 Empirical Application I now derive two expressions that test for the contributions of Ricardian and HO forces in determining why di? rent countries produce di? ering baskets of goods. I ? rst derive a “ restricted expression” that tests whether the relationship between factor intensity, factor abundance and production can be explained by HO and/or Ricardian forces. Unfortunately, it says nothing about the role of Ricardian productivity that is uncorrelated with factor intensity. To assess the role of productivity that is uncorrelated with factor intensity, I then derive an " unrestricted expression. " To derive the restricted expression, I log-linearize the expression for relative revenue in industry z (equation 13) as a function of ln (? z)) with the appropriate subscripts for country c relative to p c . The use of log revenue and not market share (v(z)) allows me to more easily and transparently control for country and industry ? xed e? ects using country-time and industry-time ? xed e? ects. I then take the covariance of this expression with z: ? cc t ? var(z). ? cc t ? cov[z, r(z)cc t] = ? ln ? (29) I further assume that the elasticity of relative factor prices with respect to relative endowments ? ? is constant and equal to ? ? 0 where ln(?) = ? ln(S/U). This allows me to write the following ? expression: ? S ? U cov[z, r(z)cc t] = ?? ln ? var(z) ? ln (? cc t) var(z) ? cc t (30) This expression decomposes the covariance of production with skill intensity into that due to factor abundance and that due to Ricardian productivity di? erences. This expression can then be taken to the data using the following estimation equation where a vector of time ? xed e? ects T allows the results to be invariant to the choice of numeraire: 14 S U cov[z, r(z)ct] = ? 0 + ? 1 ln 14 ct + ? 2 ln (?)ct + ? t Tt + ? ct ? S ? U (31) This can be seen by rewriting cov[z, r(z)cc t] as cov[z, r(z)ct ? r(z)c t] = cov[z, r(z)ct]? cov[z, r(z)c t] and ln ? S U ct cc t as ln ? ln S U c t 18 ? 1 = ?? var(z) > 0 ? 2 = ?? var(z) > 0. Under the null hypothesis that HO alone is responsible for any relationship between factor intensity, factor abundance and production, ? 1 > 0 and ? 2 = 0. Under the null hypothesis that there are no HO forces at work and that any di? erences in production are due to di? erences in Ricardian TFP, ? 1 = 0 and ? 2 > 0. If both HO and Ricardian e? ects explain why specialization occurs, then ? 1 > 0 and ? 2 > 0. This " restricted expression" does not allow for TFP that is uncorrelated with factor intensity to play any role in determining production patterns.

To examine the contribution of TFP that is uncorrelated with factor intensity, I derive the " unrestricted expression" by again starting with a log-linearized version of equation 13 where the linearization occurs at the z0 such that p(z0) = 1: 15 ? ? r(z0) ? ln(? (z)). p ? ln(? (z0)) p r(z) = r(z0) + ? ? (32) Breaking ln(? (z)) into its components under Cobb-Douglas production gives p r(z) = r(z0) ? ? ? ? r(z0) ? a ? wu ? ln(?)z + ln(?)z + ? ? ? ? ? ln(? (z0)) p ? A(z) (33) Revenue depends on country and industry level variables as might be expected. Revenue is increasing in country level productivity (? , decreasing in the absolute wage level (wu), and increasing a ? in industry speci? c relative productivity ? A(z) . 16 If the North possesses relatively cheap skilled labor, (ln(?) < 0), then relative revenue is systematically increasing in z. If the North has systematically ? higher relative productivity in skill intensive industries, (ln(?) > 0), then relative revenue is also ? systematically increasing in z. Including ? xed e? ects that make the results insensitive to the choice of numeraire country gives the following expression where ZT is a full vector of industry-time ? xed e? ects (e. g.

Industry 311 in 1990), CT is a full vector of country-time ? xed e? ects (e. g. Japan in 1990), and ? is an error term that is clustered by country-industry (e. g. Industry 311 in Indonesia): 15 16 Taking the linearization around other relative prices does not a? ect the result. Recall that the derivative outside the brackets is negative. 19 r(z)ct = ? ? r(z0) ? ln(?)ct z ? ln(?)ct z ? ? ln(? (z0)) p A(z), ct + ? zt ZTzt + ? ct CTct + ? zct (34) Again, assuming that the elasticity of relative factor prices with respect to relative endowments (?) is constant transforms the expression into the following regression form S U (z)ct = ? 0 ln ? where z + ? 1 ln(?)ct z + ? 2 ct A(z), ct + ? zt ZTzt + ? ct CTct + ? zct (35) ? 0 = ?? > 0 ? 1 = ?? > 0 ? 2 = ?? > 0. Thus, I can gauge the validity of HO as a driving force of comparative advantage through the coe? cient ? 0 . The coe? cient on the interaction term between ln(?) and skill intensity (z), ? 1 , allows me to gauge the importance of Ricardian productivity that is correlated with factor intensities of the goods. Finally, ? 2 allows me to assess the importance of Ricardian productivity that is orthogonal to factor intensity in determining production patterns. All country level di? rences in productivity that are identical across industries in a year are absorbed into the country-time ? xed e? ects. All industry-time characteristics (e. g. average scale of industry) will be absorbed by the industry-time ? xed e? ects. Under the null that HO forces alone determine comparative advantage, ? 0 > 0 and ? 1 = ? 2 = 0. Under the null that Ricardian forces alone determine comparative advantage but that they are not confounded with possible HO forces, ? 0 = ? 1 = 0 and ? 2 > 0. Under the null that Ricardian TFP is comprised of components that are and are not correlated with factor intensity, ? = 0, ? 1 > 0 and ? 2 > 0. Finally, if there are both Ricardian and HO forces present but they are uncorrelated, ? 1 = 0, ? 0 > 0, and ? 2 > 0. 4 Data and Results This section outlines the data and variables used to estimate the model. The collected data set covers 24 3 digit ISIC revision 2 industries, 11 years (1985-1995), and the following 20 countries: 20 Austria, Canada, Denmark, Egypt, Finland, Great Britain, Hong Kong, Hungary, Indonesia, India, Ireland, Italy, Japan, Norway, Pakistan, Portugal, South Korea, Spain, Sweden, and the United States.

All variables (except those explicitly mentioned) are taken from the World Bank's Trade and Production data set (Nicita and Olarreaga, 2001). All country-years for which complete data exist for at least 15 of the 24 industries in that country and year are kept. 17 Because not all countries have available data in all years, the dataset is an unbalanced panel. The Data Appendix lists the data availability for years and countries. The most binding constraint in assembling this data set was the availability of continuous time series for investment used to create the capital stock variables. 4. 1

Factor Abundance Although the model is applicable to any set of factors of production, I focus on skilled and unskilled labor as imperfectly substitutable factors of production as found in the Barro and Lee (2001) educational attainment dataset. 18 As a measure of S U, I examine the ratio of the population that has obtained a tertiary degree to that which does not. 19 As might be expected, Canada and the United States have the highest (average) values with S U = 0. 76 for the United States and S U S U = 0. 70 for Canada. Pakistan and Indonesia have the lowest (average) values with countries. 0. 02 for both There are 28 three digit ISIC manufacturing industries in the Trade and Production dataset. Four industries are excluded from the analysis: 314 (tobacco), 353 (petroleum re? neries), 354 (misc. petroleum and coal production), 390 (other manufactures). The ? rst three are excluded because their production values are likely to be substantially in? uenced by international di? erences in commodity taxation (Fitzgerald and Hallak, 2004). The last is excluded because its “ bag” status makes comparability across countries di? cult. All results are invariant to increasing the cuto? o having 18 of the 24 industries although the sample size and power of the empirical tests are obviously smaller. 18 I select skilled and unskilled labor as the factors of production in this model for two reasons. First, recent work (e. g. Fitzgerald and Hallak (2004)) has shown that skilled and unskilled labor possess more explanatory power in di? erences in the structure of production than capital. Second, data on skilled labor abundance (as measured by educational attainment rates in Barro and Lee (2001)) is far more comprehensive than the Penn World Tables coverage of capital per worker. 9 Data are only available at ? ve year intervals. Data for the interim years are interpolated assuming that the growth rate of the variable is constant over the ? ve years. No extrapolations are performed. Results using a broader de? nition of skilled labor are examined in the robustness section. 17 21 Table 1: Industry Skill Intensities ISIC Code 311 313 321 322 323 324 331 332 341 342 351 352 Description Food Beverages Textiles Wearing Apparel Leather Prod. Footwear Wood Prod. Furniture Paper and Prod. Printing and Publishing Industry Chemicals Other Chemicals Sample Average narrow 0. 16 0. 35 0. 13 0. 10 0. 12 0. 16 0. 13 0. 13 0. 21 0. 36 0. 42 0. 45 0. 23 zbroad 0. 36 0. 57 0. 28 0. 24 0. 31 0. 28 0. 32 0. 30 0. 44 0. 61 0. 67 0. 65 0. 44 ISIC Code 355 356 361 362 369 371 372 381 382 383 384 385 Description Rubber Prod. Plastic Prod. Pottery, China etc. Glass and Prod. Non-Metallic Mineral Prod. Iron and Steel Non-ferrous Metals Fabricated Metal Prod. Machinery (non-elec) Elec. Machinery Transport Equip. Prof. and Sci. Equip. Sample Std. Deviation znarrow 0. 19 0. 19 0. 21 0. 18 0. 20 0. 15 0. 19 0. 18 0. 20 0. 36 0. 29 0. 37 0. 10 zbroad 0. 4 0. 39 0. 50 0. 41 0. 37 0. 38 0. 41 0. 40 0. 47 0. 60 0. 55 0. 61 0. 13 4. 2 Skilled Labor Intensity of Industries Data on the skilled labor cost share (z) for each of the 24 industries come from educational attainment data by worker in the United States Current Population Survey (CPS) dataset where workers are transformed into e? ective workers using a Mincerian wage regression. The regression is run on data pooled by years (1988-1992) and industries. The Data Appendix explains the procedure in detail. I examine narrow and broad de? nitions of skilled labor. The " narrow" de? ition de? nes a skilled laborer as a worker with four or more years of college. The " broad" de? nition de? nes a skilled laborer as one who has attended any college. Table 1 presents these measures of z along with their means and standard deviations. 20 These measures line up with common priors. Among the most skill intensive industries are Scienti? c Equipment (385), Industrial and Other Chemicals (351, 352), and Publishing (342). Among the least skill intensive industries are Textiles (321), Footwear (324) and Wearing Apparel (322). It is important to note that I ssume that z is constant across countries. Similar results can be derived for CES production functions that allow both the factor intensities and the factor shares to vary across countries if the elasticity of substitution across factors is such that countries that possess relatively inexpensive skilled labor use techniques that produce more skill intensive factor shares in a given industry. 20 22 Table 2: Cov[z, r(z)] Summary Stats (182 observations) Measure of z Narrow Broad Mean 0. 0284 0. 0348 Std. Dev 0. 0171 0. 0246 Max 0. 0556 0. 0836 Min -0. 0198 -0. 0345 4. 3 Production Covariances

I calculate the covariance of (log) revenue with the skill intensity of the industries (cov[z, r(z)]) using production value from the Trade and Production dataset. Table 2 presents summary statistics for cov[z, r(z)] based on both the narrow and broad de? nitions of skill intensity. 21 4. 4 Factors of Production and TFP I follow Caves, Christensen and Diewert (1983) and Harrigan (1997) in using the solution to an index number problem to calculate productivity levels. 22 This methodology is based on a translog functional form that allows the productivity calculation to be based on any production function up to a second order approximation.

Based on this procedure, if capital (K) and homogenous labor (L) were used to produce value added (V A), the TFP productivity level between country a and a multilateral numeraire would be 21 These measures are in line with measures from other studies. For example, Fitzgerald and Hallak (2004) use a slightly di? erent measure of skilled labor and examine production in OECD countries. Using their data (table 7), I ? nd that the country that is in the 25th percentile of skilled labor abundance has a covariance of 0. 0377 and a country that is in the 75th percentile has a covariance of 0. 0698.

The values for the 25th and 75th percentile (using the broad de? nition) for my sample are 0. 0206 and 0. 0605, respectively. Appendix F contains a list of average cov[r(z), z] by country. 22 Basu and Kimball (1997) propose a method of measuring technology growth that addresses the endogeneity of factor demand and unobservable factor utilization. Unfortunately, there is a lack of demand shifting instruments that are strong both across industries and countries to control for the endogeneity of factor demand. I consider the issue of capacity utilization in the robustness section. Other estimators have been proposed in the ? m level literature that do not rely on the need for instruments (e. g. Olley and Pakes (1996)). I choose not to use estimators in this class because their theoretical derivation is very much motivated for ?

rm level studies and their use is inappropriate for industry-country level analysis. Required assumptions include that all “? rms” possess the same demand function for investment or intermediate inputs and the same exogenous factor prices. The assumption that market structure and factor prices are the same across countries is highly questionable. 23 T F P (z)a, t = V A(z)a, t V A(z)t K(z)t K(z)a, t ? K, a +? K, avg 2

L(z)t L(z)a, t ? L, a +? L, avg 2 (36) ? i, j represents the Cobb-Douglas revenue share of factor i in country j and ? i, avg is the average revenue share of factor i across all countries in the given industry. 23 K(z)t = L(z)t = 4. 4. 1 1 Nz, t c L(z)czt 1 Nz, t c K(z)czt and where Nz, t is the number of countries in the sample in industry z in year t. De? ators Very few industry level de? ators exist that allow comparison of output or value added across countries. One possibility is to assume that quality adjusted prices equate across countries due to a high substitutability and tradability of manufacturing goods and that all price di? rences should then be included as di? erences in quality. However, this relies more on conjecture than evidence. For this reason, I use the disaggregated PPP benchmark data provided by the Penn World Tables to de? ate the data. These price indexes are constructed with an explicit eye toward comparing goods of similar quality across countries. The Data Appendix addresses this in detail. 24 4. 4. 2 Labor and Capital Input In measuring TFP, I consider di? erences in the e? ectiveness of labor across countries because it is not proper to interpret di? erences in the e? ctiveness of labor as di? erences in total factor productivity. Di? erences in the e? ectiveness of labor can be modeled as unmeasured di? erences in the abundance of labor and, therefore, can be easily written into an HO model. Following Bils and Klenow (2002) and Caselli (2005), I create measures of the e? ectiveness of labor using wage 23 ? is constrained within a country within an industry (e. g. Indonesia-311) with no time series variation. I do this because measured revenue shares are very noisy and there is little reason to think that they are allocative.

Although they work with cost shares and not revenue shares, Basu, Fernald, and Kimball (2006) also constrain their factor shares. Labor's factor share of value added is calculated as wages' proportion of value added. Capital's share of value added is one minus labor's share. Observations where the factor share of any input is negative are dropped. 24 Country level PPP price de? ators are incorrect because of the weight that they assign to non-traded goods which leads to a greater dispersion in price indexes than occurs in manufacturing which is highly traded.

In addition, any country level output de? ators will be di? erenced out by the country-year ? xed e? ects. See Kravis, Heston and Summers (1982) for a thorough discussion of the process behind the collecting of the data and the preparation of the price indexes that are behind this study and the Penn World Tables. Country averages only capture 35% of the variance of relative prices across countries and industries in the disaggregated PWT data. This suggests that using country level price de? ators will not capture substantial within-country variation. 24 Table 3: E? ective Labor Across Countries

Country Austria Canada Denmark Egypt Finland Great Britain Hong Kong Hungary Indonesia India E 2. 55 2. 99 2. 91 1. 59 2. 78 2. 64 2. 58 2. 64 1. 54 1. 61 Country Ireland Italy Japan Korea Norway Pakistan Portugal Spain

Sweden United States E 2. 60 1. 96 2. 73 2. 74 3. 06 1. 35 1. 72 1. 95 2. 80 3. 32 premium and educational attainment data. De? ne E as the e? ectiveness of labor per worker so that EL is the e? ective labor input. Using the Barro and Lee data on average years of schooling, I normalize the e? ectiveness of labor with “ no schooling” (0 years) to be E = 1.

Following Caselli (2005), I assume that labor becomes 13% more e? ective per year for the ? rst four years of schooling, 10% per year for years 4-8, and 7% per year after that. Because the evolution of the skill level of labor in a country is likely to be slow, I use average years of schooling in 1990 for these calculations. Table 3 presents measures of E based on this methodology. These measures line up with commonly held priors. Unlike work such as Harrigan (1999) and Keller (2002), I do not consider di? erences in days or hours worked. Practically, hours worked data that is su? iently comparable across industries and countries is not available. Harrigan (1999) and Keller (2002) sidestep this issue by imposing measures of hours worked in aggregate manufacturing on all sectors within manufacturing. My interest in cross-industry TFP comparisons allows me to not include these measures. This is because hours of labor input will be highly correlated with (if not identical to) hours of capital service. If the production function is constant returns to scale, then it will also be homogenous of degree one in hours worked. If I use the same measure of hours worked in manufacturing across all manufacturing 25 ndustries, I will multiply each production function in a given country-year group by the same scalar. This scalar will then be di? erenced out by a country-year ? xed e? ect as derived in section 3. 1. 25 Labor is decomposed into operatives (U) and non-operatives (S) using data from the United Nations General Industrial Statistical Database. 26 The e? ectiveness of labor is assumed to augment both operatives and non-operatives. Capital is calculated using the perpetual inventory method. 27 The (value added) measure of productivity between country a and the multilateral numeraire is then ? S, a +? S, avg 2 ? U, a +? U, avg 2 ?

K, a +? K, avg 2 T F Pa, t 4. 4. 3 V Aa, t = V At St Et Sa, t Ea, t Ut Et Ua, t Ea, t Kt Ka, t . (37) Plausibility of TFP Measures Because of the importance of TFP measures in this paper, I check their plausibility. First, I compare my measures to those calculated by others for consistency. Second, I check the correlation of TFP across industries with revenue. If Ricardo's original insight is fundamentally true, this correlation should be positive. Last, I check how much these measures ? uctuate over time because large ? uctuations would suggest substantial noise in my calculations. My measures meet all of these criteria for desirability.

First, Table 4 presents my estimates of industry level productivity against similar measures calculated by Harrigan (1999) (Table 1). I compare all industries and countries for which our This can also be applied to the adjustment to the e? ectiveness of the labor force. If both capital and labor are equally more e? ective in some countries, this country speci? c term will be di? erenced out by the country-year ? xed e? ects. 26 These UNGISD data on operatives and non-operatives are commonly used to distinguish skilled and unskilled workers within a given country as in Berman, Bound and Machin 1998). However, using it to compare skilled and unskilled workers across countries is highly dubious. For example, the ratio of non-operatives (commonly thought to be " skilled") to operatives (commonly though to be " unskilled”) is 0. 21 in Indonesia, 0. 38 in the United States, 0. 85 in Japan, and 0. 45 in Italy (U. N. , 1995). Given the levels of e? ective labor calculated in Table 3, these numbers are not likely to represent di? erences in average skill across countries. Comprehensive data on operatives and non-operatives are not available from year to year.

For this reason, I calculate the average proportions of employment that are operatives and non-operatives for each country-industry. Using the available data, these average measures capture 95% of the year to year variation in a ? xed e? ects regression. I then apply these constant proportions to annual employment data from the Trade and Production dataset to create annual measures of operatives and non-operatives. I follow a similar procedure to decompose wages into those paid to operatives and non-operatives to calculate the measures ? S and ? U . 27 See the Data Appendix for more details. 25 26 alculations of TFP overlap. I calculate TFP of industries 382 (Machinery, non-electric), 383 (Machinery, Electric), 384 (Transport equipment), and 385 (Professional and Scienti? c Equipment). I then calculate them relative to the average across these four industries and then relative to the United States in that industry. I then compare these to similar measures from Harrigan (1999). 28 Despite di? erences in our calculations (e. g. labor input and industry level de? ators), our measures of relative TFP line up broadly. The rank correlation between the two measures based on the 24 observations is 0. 4. 29 In addition, although not presented, selected industrial levels line up with other work. For example, Japan is the world leader in TFP for Iron and Steel (371) and Non-Ferrous Metals (372) which is consistent with Dollar and Wol? (1993) and Harrigan (1997). One discrepancy between the calculations here and those of Harrigan (1999) is the lower average TFP level in scienti? c and professional equipment (ISIC 385) that I calculate relative to his calculations. However, some consolation should be taken from the fact that both calculations ? nd that the United States, Canada and

Finland are among the most productive while Italy and Great Britain are among the least productive. I also examine cov[? (z),? (z)] a r var(? (z)) a to gauge the explanatory power of productivity across industries. I calculate this measure for two reasons: ? rst, this statistic should be positive for any non-pathological model. Second, it can be shown that this number should be equal to ?? as de? ned in equation 15. For 182 observations, each indexed by country-year, the mean is 0. 3572 and signi? cantly di? erent from zero at the 1% level of certainty (t = 3. 24). 0 Because this is a reduced form combination of structural parameters, it is di? cult to interpret. However, Anderson and van Wincoop (2004) estimate that international trade barriers impose a total of a 74% ad valorem tax equivalent. Relating this number to the expression for ? evaluated at p(z) = 1 and Y /Y ? = 1, this value implies a value ? I compare my measure for ISIC 382 to Harrigan’s (1999) “ Non-electrical machinery”, ISIC 383 to his “ Electrical machinery”, ISIC 384 to his “ Motor vehicles” and 385 to his “ Radio, TV, & communications Equip. ” Although our methods for calculating TFP di? r somewhat, our measures should line up broadly. He also calculates TFP for “ O? ce and Computing Equipment” and “ Aircraft” but my industrial classi? cation does not allow for easy comparison of these industries. In addition, he also calculates TFP for Australia, Germany and the Netherlands, none of which I calculate because of data constraints. Finally, I drop his 1988 measure for Motor Vehicles in Italy which increases four-fold from the previous year in his measures and is unlikely to be accurate. 29 This is obviously excludes the values for the United States that are set equal to 1. 0 for normalization. Without the normalization, I can also compare each measure relative to country mean and include the measures for the United States. The rank correlation for these measures is 0. 76 based on 28 observations. 30 With standard errors clustered by country. 28 27 Table 4: Comparing Relative TFP Measures Harrigan (1999) ISIC Industry 383 384 1. 005 0. 681 0. 934 0. 244 1. 116 0. 425 0. 904 0. 377 0. 818 0. 586 0. 621 0. 277 1. 000 1. 000 ISIC 383 1. 663 2. 325 1. 361 1. 807 1. 711 1. 771 1. 000 Industry 384 0. 688 0. 468 0. 294 0. 477 0. 826 0. 39 1. 000 Country Canada Finland Great Britain Italy Japan Norway United States 382 0. 980 1. 009 0. 613 0. 782 0. 861 0. 811 1. 000 385 0. 335 0. 334 0. 321 0. 221 0. 287 0. 326 1. 000 382 0. 952 0. 981 0. 596 0. 760 0. 837 0. 788 1. 000 385 0. 755 0. 945 0. 655 0. 673 0. 691 0. 664 1. 000 Rank correlation between constructed measures and those of Harrigan (1999): 0. 74 of ? = 9. 5 if ? = 1. 74. Although this is in the upper range of values for ? , it is within reason. 31 Third, the measures of total factor productivity are also relatively stable over time.

Running a regression of a(z)ct on a full set of country-industry ? xed e? ects (e. g. Indonesia, ISIC-311) explains ? 91% of the variance as measured by the unadjusted R2 . Therefore, although these measures almost surely capture some business cycle ? uctuations, the variance is dominated by the larger di? erences that exist across countries and industries rather than ? uctuations over time within a country and industry. The covariance terms (?)

are then calculated using the skill labor shares (z) and value added productivity. Recall that ? is de? ned as follows: cov[z, aczt] var(z) ct = exp where cov[aczt , z] = z (38) (aczt ? aczt) (z ? z) Nct (39) where aczt is average (log) productivity across all industries for country c in year t, z is the average Broda and Weinstein (2006) estimate ? for 256 industries and ? nd that the 5th and 95th percentiles of the distribution are 1. 2 and 9. 4, respectively. 31 28 skilled labor intensity across industries and Nct is the number of industries that the summation is taken over. Because the covariance is between z and a(z), all country speci? c e? ects are di? erenced out (e. g. country level business cycles).

In conclusion, although all comparisons of TFP across countries, industries and time are subject to some di? culties in measurement, the measures presented here are very likely to re? ect real di? erences in TFP based on similarity to previous studies, the positive correlation of productivity and revenue across industries within a country in a given year, and the stability of the estimates over time. Because all measures are relative to a numeraire, the means of ln(? narrow), ln(? broad), and ? ? ? S ln(U) lose meaning but their standard deviations are 1. 29, 1. 00, and 0. 901 based on 182 observations. Consequently, no force for comparative advantage possesses substantially more variance than others. 5 Results I present two sets of results. First, I present a “ restricted” version of the model where the dependent variable is cov[z, r(z)ct]. This expression allows me to ask to what degree a country specializes in the production of skill intensive goods due to HO and Ricardian e? ects. Second, I present “ unrestricted” results where the dependent variable is r(z)ct . This allows me to gauge the determinants of revenue, industry by industry instead of based on country level covariances.

Finally, I present a robustness section to show that the results are insensitive to using IV regression to correct for classical measurement error in the productivity measures, a broader de? nition of skilled labor abundance, exchange rate volatility, and capacity utilization. I also show that the dynamic correlation of the error terms in the panel regression does not a? ect the resulting coe? cients. In addition, I show that my results are not sensitive to the imposition of the Cobb-Douglas cost shares for the U. S. by obtaining similar results using the skill rank of the industry both within the U. S. and within each country. . 1 Results: Restricted Recall that the " restricted" regression equation is: 29 Table 5: Restricted Regression Narrow z Variables ln(S/U)T (1) 0. 0109??? (0. 0033) (2) Dependent Variable: cov[r(z), z] Broad z (3) 0. 0174??? (0. 0041) (4) 0. 0175??? (0. 0036) 0. 0033 (0. 0028) 182 yes 0. 4230 182 yes 0. 4411 0. 0115??? (0. 0025) 0. 0031 (0. 0018) ln(?) Obs Time Fixed E? ects R2 182 yes 0. 3477 182 yes 0. 3996 *** estimated at the 1% level of certainty, ** estimated at the 5% level of certainty Robust standard errors clustered by country. Each observation is indexed by country-year. cov[z, r(z)ct] = ? 0 + ? 1 ln

S U ct + ? 2 ln (?)ct + ? t Tt + ? zct (40) Column (1) of Table 5 tests the hypothesis that the abundance of skilled labor as measured by the S proportion of workers with a tertiary education or higher, (U)T , predicts how skewed productive resources are towards relatively skill intensive industries (cov[z, r(z)]). Column (2) includes ln(?) to assess the importance of productivity that is correlated with skill intensity. Columns (3)-(4) do the same except that skilled labor intensity now uses the broad de? nition of skilled labor. Robust standard errors are clustered by country and presented in parentheses.

I highlight three results. First, each column contains the familiar HO result that countries with a relative abundance of skilled labor produce relatively more skilled inte