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MODELING HECKSCHER-OHLIN COMPARATIVE ADVANTAGE IN REGRESSION EQUATIONS: A CRITICAL SURVEY

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1. INTRODUCTION

Ever since LEONTIEF's (1953, 1956) pathbreaking work, empirical research has played a vital role in the development of trade theory, and "testing trade theories" has become an important part of trade theorists' agenda.[1]

But reshaping a theory that had largely been dominated by abstract two-dimensional models towards ready empirical application or testing turned out to be an arduous task. Accordingly, much of the empirical research in international trade has relied more heavily on intuition than on rigorous theory. Quite frequently this has complicated a correct interpretation of empirical results, and, as DEARDORFF (1984, p. 468) has pointed out, *"empirical tests of the theories are often faulted on the grounds that they test propositions that do not derive rigorously from the theories"*.[2]

As regards the Heckscher-Ohlin theory, early empirical work has followed Leontief insofar as it focussed on the factor content of trade, whereas later on, in the early seventies[3], the theory also began to be interpreted as determining the commodity composition of trade, and regression analyses relating trade patterns to factor intensities became increasingly popular[4].

But the present state of the factor proportions theory suggests that it is much more difficult to find a rigorous theoretical justification for such regression analyses than for

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1 See the two important general surveys by STERN (1975) and DEARDORFF (1984).

2 Similar concerns have been expressed by LEAMER (1984, p. 46): "... much of the literature on testing trade theory flounders precisely because inadequate effort was made to define the theory to be tested".

3 Beginning with BALDWIN (1971), BRANSON & JUNZ (1971), and BRANSON (1971).

4 Throughout this paper, I am only concerned with regression models trying to explain commodity trade, and regression models with indirect factor-services trade (factor contents of net exports) as dependent variables will not be considered. This can be justified by the fact that the vast majority of regression analyses in the empirical literature views the Heckscher-Ohlin theory as explaining the commodity pattern of trade, the only exceptions, to my knowledge, being HARKNESS (1983) and BOWEN, LEAMER & SVEIKAUSKAS (1987).

factor content studies.[5] Hence, it is not surprising that, in general, these regression studies were carried out on an intuitive basis, without any explicit reference to rigorous formulations of the factor proportions theory.

What appears to make this problem particulary disturbing is the fact that the factor proportions theory so far seems to rely more heavily on regression studies than on factor content studies for its empirical support.[6] This certainly adds to the motivation for the effort undertaken in the present paper to explore the possible links that one can find between rigorous formulations of the factor proportions theory and its empirical examination in a regression framework. The paper tries to bring together in a systematic way, and to evaluate the various ways that can be pursued to narrow the above mentioned gap in the theoretical justification of regression tests of the factor proportions theory.

Lest the expectations are to high, let me mention two general observations at the outset, that would lead one to be rather sceptical as to the possibility of using the factor proportions theory to derive, in the strict sense of the word, a structural relationship explaining the commodity pattern of trade by factor intensities and factor abundance, which could be used as a regression equation in empirical work.

First, the factor proportions theory has typically been formulated in a nonparametric way. While the set of assumptions frequently employed to reduce the complexity of the model to manageable proportions is, admittedly, rather restrictive, tastes and technologies, the "givens" of the theory, have usually not been represented in parametric forms. The same, then, holds true for the propositions derived from such a model. On the other hand, traditional econometric theory interprets a regression equation as just that: a parametric representation of a data generating process.

Secondly, and maybe more importantly, neoclassical theory of production and trade has been shown by SAMUELSON (1953-54) and others[7] to leave indeterminate the precise commodity pattern of international production and trade in the case of more commodities than factors if there is factor price equalization through trade.

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5 Note, however, that recent developments have shown that Leontief's way to infer factor abundance from the factor content of trade may be erroneous in the general case (LEAMER, 1980 and AW, 1983.a).

6 See DEARDORFF's (1984) survey.

7 See TRAVIS (1964, pp. 136 ff.), MELVIN (1968), BHAGWATI (1972), DEARDORFF (1979), and ETHIER (1984).

Given these two general observations, one should not expect the factor proportions theory to offer sufficient information in order to completely specify a regression model explaining commodity trade by factor intensities and factor endowments. To a certain extent, regression analysis of international trade will continue to rely on some form of intuition, but the present paper suggests that the factor proportions theory contains more information that can be used for the specification of regression models than has often been used in empirical research.

2. GENERAL FORMULATIONS OF THE FACTOR PROPORTIONS THEORY

As indicated in the introduction, the problem that we are having with regression applications of the factor proportions theory is partly one of dimensionality. Application in regression analysis, of course, requires the theory to be formulated free of any dimensional restrictions. But early attempts of theoretical analysis in higher dimensions have revealed an indeterminacy problem on the commodity level.

That, of course, does not mean that anything can happen on the commodity level in the general case of many goods, factors and countries. Meanwhile there are generalized formulations of the factor proportions theory, and it is natural to start off with a kind of stocktaking.[8]

Two different types of such formulations are currently available. The first are factor content models of international trade going back to VANEK (1968), the second are correlation results as pioneered by DEARDORFF (1980, 1982).

2.1 Factor Content Models

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8 For a more detailed and comprehensive survey of higher-dimensional trade theory, see ETHIER (1984). That study does not, however, address the problem of how to use the factor proportions theory to specify a regression model.

Factor content models are remarkably simple but relying on a set of rather restrictive assumptions. Assuming

a) linearly homogeneous production functions, identical across countries,

b) free trade under perfect competition,

c) international factor price equalization through trade,

d) homothetic preferences, identical across countries, and

e) fully employed factors,

it can be shown that the factor services embodied in any country j's vector of net exports, $\mathbf{t}_j$[9], is equal to a weighted difference between its endowment vector, $\mathbf{f}_j$, and the rest of the world's endowment vector, $\mathbf{f}_{jR}$:[10]

$$\mathbf{B}\mathbf{t}_j = (1-a_j)\mathbf{f}_j - a_j\mathbf{f}_{jR}, \qquad (1)$$

where **B** is a matrix of cumulative factor input coefficients with appropriate dimensions, a_j is the share of country j's absorption in world GDP.

Various attempts have been made to relax some of the above assumptions. BERTRAND (1972) has shown that differing preferences for home-made and foreign products can, in a somewhat rudimentary way, be incorporated into the model without any change in the formal structure of the core equations. Furthermore, LEAMER (1984, pp. 39-41) has shown that allowing for nonhomothetic preferences in the form of income-dependent consumption leads to a relatively modest modification only affecting the way that labour endowment differences are linked to the factor content of trade.

As regards production functions, HELPMAN & KRUGMAN (1985, p. 57) have pointed out that, because the Heckscher-Ohlin-Vanek (HOV) model only contains equations relating to post-trade equilibrium, international economies of scale as analysed by ETHIER (1979, 1982) do not invalidate the basic propositions of the model. The same does not, of course, hold true for conventional economies of scale.

Assuming international factor price equalization through trade implicitely restricts the analysis to situations, in which countries do not lie "too far apart" in terms of their factor

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9 Throughout this paper boldfaced letters will indicate vectors or matrices for an easy distinction from scalars.

10 The relevant literature contains several explicit derivations of equations like (1), so that such a derivation can be omitted here. See, for instance, VANEK (1968), HORIBA (1971), BERTRAND (1972), WILLIAMS (1977), and LEAMER (1980).

endowments.[11] Without factor price equalization there are country–specific factor input coefficients, and this, one would assume, requires using a large number of foreign B–matrices to calculate the factor content of imports and hence net exports. As shown in the appendix, relaxing the assumption of international factor price equalization in the case of only two countries (j and l) leads to the following modification of equation (1):

$$(a_l B_j + a_j B_l) t_j = a_l f_j - a_j f_l - a_j a_l (F_j - F_l), \qquad (2)$$

where $a_l = 1 - a_j$, and F_j and F_l denote endowments that would be required to produce world output using country j's and country l's factor input coefficients, respectively. The left hand side of (2) would indicate that the error one commits by using equation (1) under non–equalized factor prices is the smaller the smaller the country in question[12], but the last term on the right hand side is independent of country size. In the general case of more than two countries the situation becomes considerably more complex, because there is always more than one country where imports can come from.

However, there is the following trade–off in assumptions if the model is formulated in value terms. Under Cobb–Douglas production functions the assumption of factor price equalization can be relaxed without any complication in the central equations of the model.[13] This is because a value terms formulation changes factor input coefficients to "factor shares"[14], which are parametric and hence independent of factor prices under Cobb–Douglas technologies. It can easily be shown that the following equation holds irrespective of factor price equalization, if production functions are of the Cobb–Douglas type:

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11 More precisely, the implication is that the countries' endowments all lie in the so-called "factor-price-equalization region" (TRAVIS, 1964, pp. 15-19) or, equivalently, that they belong to the "factor-price equalization set of endowment distributions" (HELPMAN & KRUGMAN, 1985, pp. 13-15).

12 This argument, as put forward by WILLIAMS (1977), has sometimes been alluded to in empirical work.

13 Another, early attempt to formulate a HOV model without factor price equalization was BERTRAND (1972). He also chose a value terms formulation for this purpose, but instead of restricting production technologies he introduced a modified demand assumption, which is in some sense more restrictive than assumption d) above. Moreover, in Bertrand's approach commodity trade and factor intensities do not appear separately, and this makes it impossible to be linked to regression analysis.

14 These "factor shares" have been introduced into trade theory by JONES (1965).

$$\theta \mathbf{Pt}_j = (1-a_j)\mathbf{V}_j - a_j\mathbf{V}_{jR}, \qquad (3)$$

where θ is the "factor shares" matrix and $\mathbf{V}_j$ and $\mathbf{V}_{jR}$ are, respectively, country j's and the rest of the world's factor endowments, all evaluated with the respective countries' post-trade factor prices.

In what follows the HOV model will be referred to as represented by equation (3), and to simplify the notation this equation is rewritten as

$$\theta \mathbf{x}_j = \mathbf{g}_j. \qquad (3.a)$$

Yet another approach to relaxing the assumption of factor price equalization in a factor content model of trade has been followed by BRECHER & CHOUDHRI (1982). Instead of deriving a vector equation like (1) or (3) they prove the following rank order proposition for the two factor (capital, labor) world: ranking countries in terms of their factor endowment ratios is equivalent to ranking them in terms of the relative physical factor content of equal values of their exports.

Finally, one might wonder about the validity of the HOV model when there are differences in production functions or new products.[15] VANEK & BERTRAND (1971) have pointed out that, as long as a sufficient number of "old products" serve as "carriers of factor price equalization", international technology differences are only of a potential nature, and no good will actually be produced by two different technologies in different countries. Under such conditions, then, the HOV model remains valid. BRECHER & CHOUDHRI (1984) have shown that this kind of argument can be generalized as follows: Whatever can be said about the factor content of trade under non-equalized factor prices (see the above remarks) is not invalidated by the existence of new products, given no single product is produced by more than one country.

Summarizing all these attempts to generalize the HOV model, it is probably fair to say that the list of assumptions stated at the beginning of this chapter should not be taken, in their entirety, as correctly indicating the limitations of this model. While it remains true that there are important limitations to its validity, the HOV model is slightly more general than

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15 Such phenomena are frequently described, in greater detail but usually less rigorously and less coherently, in what has become known as "technology theories" of international trade. For a brief survey, see DEARDORFF (1984, pp. 493-499).

these assumptions, primarily employed for conveneince of presentation, would indicate. However, one might still regard the HOV model as something like a *"clearly incredible"* (LEAMER, 1984, p. 45) model, in which case trying to use regression analysis for an empirical examination may not seem to be an issue. But, as indicated in the introduction, the conundrum is that regression studies, albeit on an intuitive basis, did, in fact, perform quite well empirically. And it is for this reason that exploring the relationship between theory and regression models is a useful thing to do.

2.2 Correlation Results

The second type of generalized formulations of the factor proportions theory are correlation results going back to DEARDORFF (1980, 1982).[16] Such correlation results give mathematical substance to the general presumption that, while it may not always be possible to exactly determine the commodity pattern of trade in generalized versions of the factor proportions theory, there must be a general validity of the Heckscher–Ohlin theorem in the weaker sense of an average commodity trade prediction.[17] Deardorff's results hold under considerably more general conditions than do the HOV equations presented above. In particular, they do not, in any way, require international factor price equalization through trade, and tastes do not have to be homothetic nor even internationally identical. Demand in every country only has to be homogeneous of degree zero in incomes and prices and it has to satisfy the weak axiom of revealed preference. But this increased generality could only be achieved at the expense of having to rely on unobservable pre–trade (i.e. autarky) information, which, in turn, limits the usefulness of these results for empirical research.

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16 Similar results have also been obtained by DIXIT & NORMAN (1980), WOODLAND (1982), DIXIT & WOODLAND (1982), and most recently by NEARY & SCHWEINBERGER (1986), all of which use duality theory. But it is probably fair to say the Deardorff's is the pioneering work in this area. See also ETHIER (1984). It should be mentioned that this literature also contains correlation results on the factor content of trade. But because of our interest in regression analysis explaining commodity trade, only propositions explicitely dealing with commodity trade are of interest here.

17 As DEARDORFF (1985) has pointed out, this corresponds to a general strategy, along which it was possible to further develop modern trade theory: trying to weaken the propositions such that they can be proved under more general conditions.

However, similar results can also be derived from the HOV model, which only uses post-trade information. Multiplying equation (3.a) from the left by $\mathbf{g}_j'$ yields:

$$\mathbf{g}_j'\Theta \mathbf{x}_j > 0. \tag{4}$$

Inequality (4) is far from trivial since individual elements of $\mathbf{g}_j$ as well as $\mathbf{x}_j$ can be negative. It should, however, be pointed out that it does not yet constitute a correlation result. But it can be shown that it does imply a positive "comvariance" of the kind discussed by DEARDORFF (1982, p. 690). The difference between Deardorff's result and inequality (4) is that Deardorff uses relative autarky factor price deviations from the world average to measure a country's factor abundance instead of the factor endowment differences represented by the individual elements of $\mathbf{g}_j$. Furthermore, the "factor shares" as defined by Deardorff use world average autarky factor prices to evaluate factor inputs, which are, in turn, defined to be actual factor inputs used by the respective country of origin.

Up to this point one seems to be faced with a rather uneasy choice between more restrictive assumptions and an empirically less useful formulation of the theory. HELPMAN (1984) has shown an interesting way out of this dilemma. He has proved a proposition on bilateral trade, similar to inequality (4), but without requiring factor price equalization or restricting preferences, and yet only relating to post-trade, that is observable, data:

$$(\mathbf{w}_j - \mathbf{w}_l)'\mathbf{B}_{jl}\mathbf{t}_{jl} < 0, \tag{5}$$

where $\mathbf{w}_j$ and $\mathbf{w}_l$ denote, respectively, vectors of factor prices observed in free trade equilibrium in country j and country l, $\mathbf{t}_{jl}$ is the vector of net commodity exports from country j to country l, and $\mathbf{B}_{jl}$ is a matrix of factor input coefficients, whose columns represent country j's (l's) cost minimizing technique, if the respective commodity is exported (imported) by country j (l) to country l (from country j). Helpman assumes there is no intra-industry trade, but if we define a vector $\mathbf{r}_{jl}$, the h-th element of which is $(w_{jh}-w_{lh})/\min(w_{jh},w_{lh})$, Cobb-Douglas production functions would allow the following reformulation of (5):

$$\mathbf{r}_{jl}'\Theta \mathbf{x}_{jl} < 0. \tag{5.a}$$

Helpman also assumes that there are no intermediate products, but STAIGER (1986) has shown that in the context of such a model the factor input coefficients in $\mathbf{B}_{jl}$ should be defined to exclude indirect inputs, given intermediate products can be freely traded.

Inequalities (4) and (5) are precise statements of the ways in which it can be said that countries, on average, tend to export (import) commodities that intensively use their relatively abundant (scarce) factors.

In what follows various ways of linking these generalized formulations of the factor proportions theory to regression studies of commodity trade will be examined.

3. TWO POSSIBLE WAYS OF JUSTIFYING REGRESSION ANALYSIS

All the above formulations of the factor proportions theory place certain restrictions on its key variables: factor endowments, factor intensities and trade. It will be argued that the problem of justifying regression analysis should now be seen as that of transforming these restrictions

a) into restrictions over specific estimators or

b) into restrictions over parameters,

such that regression analysis can be used to test the theory. Each of these will now be considered in turn.

3.1. Nonparametric use of regression analysis

If the theoretical basis of empirical work is as in a) above, one could perhaps appropriately talk about a nonparametric use of regression analysis. If $T(\mathbf{x}_j,\Theta,\mathbf{g}_j)$ is the restriction that the theory places on trade ($\mathbf{x}_j$), factor intensities (Θ) and factor endowments ($\mathbf{g}_j$), the general idea is to find a regression equation, or a set of regression equations, $R(\mathbf{x}_j,\Theta,\mathbf{g}_j;\beta_j)$ and a specific associated "estimator" $\mathbf{b}_j(\mathbf{x}_j,\Theta,\mathbf{g}_j)$, such that

$$T(\ ) = \Phi\{\mathbf{b}_j(\ )\}. \qquad (6)$$

Ideally, one should not talk about an "estimator" in this context, because there really aren't any theoretical parameters to be estimated. Regression analysis, in this case, is nothing but an alternative, and for some reason preferred[18] way of directly observing whether or not the data satisfy the restrictions T( ), which essentially is a nonparametric representation of the theory. Basically, then, we are still in the realm of descriptive statistics. Accordingly, all the test statistics usually reported in regression analysis, such as t-values, only have a rather limited meaning in this case, and they should not, strictly speaking, be used as suggested in econometrics textbooks.

The first to explicitely justify regression analysis along these lines was HARKNESS (1978). His regression equation R( ) is $\mathbf{x}_j = \Theta'\beta_j$[19] with the associated "estimator" $\mathbf{b}_j$ being the OLS "estimator", and his way of testing the theory is to compare the signs and rank order of the individual elements of $\mathbf{g}_j$ and $\mathbf{b}_j$. A subsequent discussion[20] was concerned with the validity of such a test. In the above terminology one would say it was concerned with the precise nature of the transformation $\Phi\{\ \}$. In Harkness' case T( ) is equation (3.a) above, and it is quite clear that $\Phi\{\ \}$ then is

$$(\Theta\Theta')\mathbf{b}_j - \mathbf{g}_j = 0. \tag{7}$$

Hence, for Harkness' test to be valid, the matrix $(\Theta\Theta')$ has to satisfy some rather restrictive conditions. This has been pointed out in a general way by ANDERSON (1981) and in some more detail by AW (1983.b). LEAMER & BOWEN (1981) offer a counterexample for the "even" (3x3) case showing a violation of Harkness' rank order and sign relation between $\mathbf{b}_j$ and $\mathbf{g}_j$. This discussion seems to raise doubts as to the usefulness of attempts to rescue some form of "regression interpretation" of the Heckscher-Ohlin theory.

More recently, however, FORSTNER (1985) has also applied the nonparametric approach to DEARDORFF's (1982) correlation results and HELPMAN's (1984) inequality (5). This was more successful than Harkness' attempt, because the resulting "regression

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18 Actually, it is difficult to see, why it should be more convenient to take a "regression - detour" to examine, whether or not the data satisfy the restrictions implied by the theory. See also LEAMER (1984, p. 56 and p. 58).

19 Throughout this chapter, error terms will be omitted in the regression equations, because their properties are simply irrelevant in a purely descriptive, or nonparametric, use of regression analysis.

20 See ANDERSON (1981), LEAMER & BOWEN (1981), a reply by HARKNESS (1981), and AW (1983.b).

interpretation" of the Heckscher-Ohlin theory does not depend on additional, arcane conditions. It is worthwile to explicitely apply Forstner's ideas to the present model formulation, which differs from Deardorff's in that more restrictive assumptions lead to the exclusion of non-observable variables. It will be interesting to see how the more restrictive assumptions of the present formulation translate into propositions avoiding certain limitations in empirical applicability, as mentioned by FORSTNER (1985, p. 847).

Consider, first, the following regression specification R( ):

$$x_j = g_{hj}\theta_h\beta_{hj}, \qquad (8)$$

with h = 1 ... k (k factors), where θ_h' is the h-th row of θ, g_{hj} is the h-th element of $\mathbf{g}_j$, and β_{hj} is a "parameter".[21] It is quite straightforward that, if b_{hj} is the OLS "estimator" of β_{hj}, the restriction (4) can be transformed into the following cross factor restriction $\Phi\{\ \}$:

$$\Sigma_h(g_{hj}^2\theta_h'\theta_h)b_{hj} \geq 0. \qquad (9)$$

This is because $b_{hj} = (g_h\theta_h'x_j)/(g_{hj}^2\theta_h'\theta_h)$, and $\Sigma_h g_{hj}\theta_h'x_j = \mathbf{g}_j'\theta x_j \geq 0$.

Thus, the weighted average of OLS estimators of the simple regressions (8) over all factors must be nonnegative. The larger, in an absolute sense, the factor endowment difference between country j and the rest of the world for a particular factor and the more important this factor is for the production of the traded commodities, the larger is the weight for the respective "estimator" in the restriction (9) above. Forstner's regression specification includes a constant and it translates all the regressors to the positive part of the real line. Neither is necessary for the above result. Indeed, omitting the constant makes it unnecessary to assume balanced trade. Furthermore, inequality (9) holds for every country individually, whereas Forstner's proposition relates to a cross factor – cross country average. This is an important feature, because quite frequently empirical studies cannot be designed to include many, let alone all, countries.

As an alternative to (8), R( ) might be defined as a set of kxn commodity-specific (n commodities) simple regressions:

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21 Recall, however, the above remarks relating to the use of conventional regression terminology in this case. (8) does not contain any parameters in the sense of regression analysis proper.

$$x_i = \theta_{ih}\mathbf{g}_h\beta_{ih}, \tag{10}$$

where x_i and $\mathbf{g}_h$ are, respectively, m-dimensional (m countries) trade- and endowment vectors for commodity i and factor h. By analogy to the above argument, inequality (4) translates into the following on average - restriction over b_{ih}, the OLS "estimators" of β_{ih}:

$$\Sigma_i\Sigma_h(\theta_{ih}{}^2\mathbf{g}_h'\mathbf{g}_h)b_{ih} \geq 0. \tag{11}$$

Note that there is no restriction over cross factor - averages of b_{ih} for each commodity individually. This might be interpreted as indicating the country-specific rather than commodity-specific nature of the factor proportions theory.

Next, consider the following multiple regression model:

$$x_j = (g_{1j}\theta_1, g_{2j}\theta_2, \dots, g_{kj}\theta_k)\gamma_j, \tag{12}$$

where γ_j is a k-dimensional "parameter"-vector. If $\mathbf{c}_j$ is, again, the OLS "estimator" of γ_j, $\mathbf{Z}_j$ is the regressor matrix of (12), and $\mathbf{i}$ is a k-dimensional vector of ones, the following restriction is implied by inequality (4):

$$\mathbf{i}'\mathbf{Z}_j'\mathbf{Z}_j\mathbf{c}_j \geq 0. \tag{13}$$

This is because, by definition, $\mathbf{Z}_j'\mathbf{Z}_j\mathbf{c}_j = \mathbf{Z}_j'x_j$, and

$$\mathbf{Z}_j'x_j = \begin{matrix} g_{1j}\theta_1'x_j \\ g_{2j}\theta_2'x_j \\ \vdots \\ g_{kj}\theta_k'x_j \end{matrix} \tag{14}$$

so that

$$\mathbf{i}'\mathbf{Z}_j'x_j = \mathbf{g}_j'\theta x_j. \tag{15}$$

Inequality (13) states that the cross factor - weighted average of the individual elements of c_j is positive. The h-th weight is formed by the inner product $(\Sigma_h g_{hj}\theta_h')g_{hj}\theta_h$. Hence, this time the weights are somewhat more complicated. Due to the fact that the underlying specification is a multiple rather than a simple regression equation, all the factor endowment differences appear in every single weight. For a more detailed discussion of these weights see FORSTNER (1985, p. 845).[22] As with the country-specific simple regression above, the restriction (13) holds for every country individually, not just on average across all countries.

By analogy to the simple regression case, one may also want to consider n commodity-specific multiple regressions of the following form (i = 1 ... n commodities):

$$x_i = (\theta_{1i}g_1, \theta_{2i}g_2, \ldots, \theta_{ki}g_k)\gamma_i, \qquad (16)$$

where θ_{hi} is the i-th element of the vector θ_h. In this case, the factor proportions theory as represented by (4) above implies the following on average - restriction over the individual elements of $\mathbf{c}_i$, the OLS "estimator" of γ_i:[23]

$$\Sigma_i \Sigma_h (\Sigma_h \theta_{hi} g_h') \theta_{hi} g_h c_{hi} \geq 0. \qquad (17)$$

As with commodity-specific simple regressions, theory does not place any restrictions on every c_i individually. It is the weighted sum of estimators over all factors and commodities that must be nonnegative.

It is evident that similar results can be obtained for bilateral regression equations, due to the inequalities (5) or (5.a), going back to HELPMAN (1984). Because of the formal similarity to the above analysis, an explicit derivation of such results will be omitted here.

Before turning to attempts at a genuine parameterization of the theory as the second way of justifying regression analysis by the factor proportions theory, I should like to make a final point. The general principle outlined in this chapter, along which a nonparametric use of regression analysis can firmly be justified within the factor proportions theory, is more general than the above examples might suggest. In particular, it is not limited to the OLS-"estimators". If any non-OLS "estimator" does not, in the end, use any information other

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22 Forstner correctly points out that the regressors of equation (12) above should be additively transformed such that they are all positive, in order to obtain positive weights in (13). Without such a transformation, these weights can also be negative for certain factors. Furthermore, in Forstner's anlysis the weights themselves appear in a slightly modified form, that explicitely distinguishes the strength of interactions from their similarity.

23 The proof can be omitted because it is completely analogous to that of inequality (13), except for the fact that in the case of a commodity-specific regression there must also be a summation over all commodities.

than that on factor intensities, factor endowments and trade, in other words information that the theory T( ) relates to, there must always be a restriction Φ{ } over that "estimator", which is implied by T( ).

Moreover, the theory itself, if linked to regression analysis in this way, does not suggest that trade always be the "dependent variable" in the regression model R( ). In a formal sense, trade and endowments enter the inequality restrictions above in an entirely symmetric fashion. Hence, one might just as well choose regression models, in which endowments appear as the "dependent variable". Indeed, just as it is inappropriate to talk about "parameter estimation" in the present context, it is also, strictly speaking, inappropriate to talk about "dependent variables".

However, this situation will be reversed as soon as one attempts to parameterize the theory towards equations that can be applied in regression analysis proper.

3.2 Regression analysis proper

As opposed to the previous approach, regression analysis proper requests a prior commitment to treat one of the three key concepts involved as the dependent variable and the others as exogenous ones. In the present context this commitment must be expected to acknowledge the "trade theory – nature" of the factor proportions theory in that trade is treated as the dependent variable, and factor endowments and factor intensities are regarded to be exogenous. This is less innocuous than it may seem. It means, for instance, that in a cross country study factor endowments are stochastically independent of the error term of whatever kind of regression equation one chooses to work with. As BOWDEN (1983, p. 221) has pointed out, it may well be that a country is abundantly endowed with a particular factor, because some non-Heckscher-Ohlin advantage leads it to heavily export commodities using that factor intensively. Econometric theory, of course, offers a straightforward remedy for such a situation: simultaneous equations methods. One would have to somehow extend the regression equation to capture these non-Heckscher-Ohlin determinants of trade and then endogenize endowments via a second equation.

These remarks reveal a great advantage of trying to justify applying or testing the factor proportions theory in regression analysis proper rather than in a purely descriptive use of regression analysis, as outlined in the previous chapter. It explicitely acknowledges the partial nature of the factor proportions theory by there always being an error term (somehow representing other trade theories and trade barriers), and econometric theory forces one to think about the stochastic properties of this error term, that is to think about how these other determinants of trade, however vague the notion of them may be, might be linked to the factor proportions theory in terms of the regression equation at hand.[24] But how can such a regression equation be derived from the theory.[25]

In one way or another, the parameters to be estimated in such a regression equation would have to be interpreted as partial derivatives of net exports with respect to factor intensities or factor endowments, or some combination of both. To my knowledge, the only formulation of the factor proportions theory in terms of such partial derivatives has been offered by DIXIT & WOODLAND (1982). It may be useful just to state their respective result in order to see how difficult it is to justify regression tests of the theory along these lines. In terms of the present notation, the partial derivative of net exports of commodity i with respect to the domestic endowment with factor h is (omitting the country index, for ease of notation):

$$t'_{ih} = \{k/(1-k)\}\{\delta_{ih} - (w_h f_h/y)\}\{q_i/f_h\}, \qquad (18)$$

where δ_{ih} is the partial elasticity of output of commodity i, q_i, with respect to factor endowment, f_h, the so-called Rybczynski elasticity, and w_h is the post-trade price of factor h (DIXIT & WOODLAND, 1982, p.212). It should be emphasized that the partial

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24 The ideal situation would be to have a complete regression model that combines, in a rigorous way, the factor proportions theory with all the other determinants of trade that we commonly analyse in distinct partial models. As LEAMER (1984, p. 45) has emphasized, it would only be in such a situation that the factor proportions theory could be treated as the maintained hypothesis and formally tested against alternative hypotheses. However, we should not expect to be able to derive any such all-encompassing model from theory. Indeed, it is questionable whether or not the efforts should go in that direction at all. Hence, all we can do at present is to stick to the one theory that has most carefully and rigorously been formulated, try to reformulate and parameterize it, such that it is amenable for regression analysis proper, and then try to take account of non-Heckscher-Ohlin determinants in an ad hoc way by appropriate estimation or explicit modeling.

25 Recall that the above regression equations (8), (10), (12) and (16) have not, in this sense been derived from theory. Their link to the theory was established through specific "estimators". Deriving a regression equation from theory by paramterizing it, on the other hand, leaves the choice of specific estimators open to statistical considerations, as is usual in regression analysis proper.

derivative as stated in (18) is a general equilibrium one and that it is evaluated at the point of no trade, where the domestic endowment is strictly proportional to that of the rest of the world, the proportionality factor being k.

The important thing to note about this partial derivative is that there is no obvious way, in which one can show that its sign unambiguously depends on some notion of factor intensity, as the usual interpretation of regression results presupposes.[26] Hence, this result raises serious doubts as to the possibility of finding an explicit justification of regression analysis proper through a partial derivatives formulation of the factor proportions theory.

DEARDORFF (1984, pp. 485–486) has tried to find some justification for regression analysis by formulating the theory with a parametrized representation of the production – and demand side of the economy. Assuming Cobb–Douglas functions to represent preferences as well as production possibilities, all identical across countries, he could show that commodity prices in autarky relative to free trade[27] commodity prices are related to a factor endowments vector in a loglinear way via the matrix Θ:

$$\mathbf{r}_j = \Theta'(\mathbf{v}_W/y_W - \mathbf{v}_j/y_j) \quad , \qquad (19)$$

where $\mathbf{r}_j$ is a vector of logarithmic price differences between autarky in country j and the world under free trade, $\mathbf{v}_W$ represents a vector of world endowments, expressed in logs (accordingly for $\mathbf{v}_j$)[28], and y denotes GDPs. The problem, of course, is that $\mathbf{r}_j$ is unobservable and that theory does not tell us precisely, how $\mathbf{r}_j$ is linked to $\mathbf{t}_j$ or $\mathbf{x}_j$. As pointed out by DEARDORFF (1984, pp. 471–472), for the present purpose, the ideal case would be to have $\mathbf{t}_j$ being a linear, sign-reversing transformation of $\mathbf{r}_j$, but that is something existing theory simply does not imply.[29] It is the fundamental indeterminacy problem of neoclassical theory of production and trade mentioned in the introduction that

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26 Even in the so-called "even" case, in which the number of goods equals the number of factors, some arcane conditions must be met in order to have an unambiguous sign structure, unless this number is two. See the discussion in DIXIT & WOODLAND (1982, p. 212-213).

27 Here, free trade is assumed to lead to international factor price equalization.

28 Note the similarity between the factor endowments vector in (19) and g_j in (3.a) above.

29 For a detailed analysis of how autarky price differences can be misleading as predictors of trade patterns, see DRABICKI & TAKAYAMA (1979).

ties in at this stage, and there seems to be no way to avoid the conclusion that the factor proportions trade theory does not allow any rigorous justification of regression analysis proper.[30] Hence, we are left with the question of what intuitive steps are necessary to obtain a parameterization of existing formulations of the factor proportions theory, that would lend itself to regression analysis proper.

For this purpose, let us come back to the bilinear form (4). This can be interpreted as saying that net exports of commodity i must, in some sense on average across all commodities, be the higher, the higher the inner product $\mathbf{g}_j'\theta_i$, where θ_i is the i-th column of θ. We do not, within the factor proportions theory, have sufficient theoretical information to precisely specify this average relationship between x_{ij} and $\mathbf{g}_j'\theta_i$ in terms of a functional form, so the next step must necessarily be an intuitive one.

An interesting approach has been followed by BOWDEN (1983, pp. 216-217), who views a parameterization of this relationship as freeing the individual coefficients in the inner product from unity. Given the interpretation of (4) as an explanation, in some average sense, of x_{ij} by $\mathbf{g}_j'\theta_i$, we can write

$$x_{ij} = \Sigma_h \alpha_{ihj} g_{hj} \theta_{hi} + u_{ij}, \qquad (20)$$

where α_{ihj} are genuine commodity- and country-specific parameters (Bowden's coefficients freed from unity), and u_{ij} is an error term.

It may be argued that getting from (4) to (20) involves a rather large step, and this is undoubtedly true. But some step of this kind is simply necessary as a bridge between the available formulations of the factor proportions theory and regression analysis proper. It should be pointed out at this stage that the need to introduce intuitive steps in an otherwise rigorous derivation places the resulting hypotheses in the "class" of intuitive ones. For this reason, one might question the advantage of the present modeling attempt over other regression specifications that are purely intuitive in that they do not discuss their relationship to rigorous formulations of the factor proportions theory. A further discussion of this issue would lead one to deeper-lying questions of scientific methodology, and to

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30 DEARDORFF (1984, pp. 472-473) suggests to explicitely allow for such things as transport costs, imperfect competition or tariffs and other trade barriers in order to obtain a well defined relationship between r_j and t_j or x_j. But this is more of an agenda for future research than a presently available solution to this problem.

some extent, I would be willing to agree, an evaluation of different modeling attempts is also a matter of taste. But the basic argument I would put forward in defense of the present attempt is that it tries, as much as possible, to use the relevant information offered by rigorous theory in deriving the hypothesis to be tested. And in doing so, it arrives at regression specifications that may be different in important respects from regression equations that are specified on a purely intuitive basis. It will be seen that the present approach, while it does not enable one to rigorously derive a complete regression specification, nonetheless concludes with strong suggestions regarding certain specification issues that a purely intuitive approach will typically not be able to resolve, like the choice of the dependent variable, or the way that factor intensities and factor endowments should be measured when used as regressors.

Inequality (4) is a restriction across commodities and factors that must hold in post-trade equilibrium. Equation (20), on the other hand, views net exports of each commodity individually as the outcome of a stochastic process, the systematic part of which are the interactions of factor intensities with factor endowments. If (20) is to be seen as an, admittedly arbitrary, parameterization of (4), we are not, of course, free to assume any error term and admit any parameter values. If u_{ij} is to have a vanishing expectation, the parameters α_{ihj} must, in some sense on average across all i, h and j, be positive. Otherwise the outcome of this stochastic process cannot satisfy the restriction (4), except by coincidence.

To preclude any misunderstanding, inequality (4) does not allow every individual x_{ij} to be seen as a monotonically increasing function of individual interactions, or even the inner product $\mathbf{g}_j'\theta_i$. For the moment, one seems to be trapped with vague notions of averages across commodities. To some extent, however, this is due to the extensive parameterization involved in (20). In fact, (20) must be called an overparameterization in the strict sense of the word, because there are necessarily more paramters (mxkxn)[31], than we can hope to estimate with all available observations of trade (nxm). In order to obtain an estimable regression model, the dimensionality of the parameter space must be reduced by suitable assumptions. Depending on whether we view the stochastic process (20) as being country-

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31 m, n, and k denote, respectively, the number of countries, commodities and factors.

specific or commodity-specific , we can either assume $\alpha_{ihj}=\alpha_{hj}$ for all i or assume $\alpha_{ihj}=\alpha_{ih}$ for all j, such that we have

$$\mathbf{x}_j = \mathbf{Z}_j\alpha_j + \mathbf{u}_j, \tag{21}$$

and

$$\mathbf{x}_i = \mathbf{Z}_i\alpha_i + \mathbf{u}_i, \tag{22}$$

where $\mathbf{Z}_j$ and $\mathbf{Z}_i$ are, respectively, the regressor matrices of (12) and (16), α_j and α_i are vector representations of α_{hj} and α_{ih}, and $\mathbf{u}_j$ and $\mathbf{u}_i$ are corresponding vector representations of u_{ij}.

Thus we are back to the interactional regression models of the previous chapter, but this time there is a direct, though to some extent intuitive, link between these models and the factor proportions theory, whereas formerly such a link could only be established through a specific "estimator" (OLS). This is more than hairsplitting; because now we are free to choose any estimator for the α-parameters, depending on how we see the stochastic properties of the error term. Up until now the emphasis was on the expectation of this error term, and it was pointed out that, from the point of view of the factor proportions theory, a zero expectation implies a rather unspecified cross commodity - restriction on the parameters. As for its variance, the factor proportions theory itself does not appear to pose any problem also assuming homoscedasticity. But when it comes to empirical work, one has to acknowledge the partial nature of the factor proportions theory by explicitely considering how non-Heckscher-Ohlin determinants of trade might interfere with classical disturbance assumptions in equations like (21) and (22). Accordingly, some departure from OLS in the estimation procedure may be needed.

Without going into detail one might, for instance, expect there to be some country-specific non-Heckscher-Ohlin determinants. In a cross-country application of equation (21), i.e. estimating equations like (21) for several countries separately, these determinants could, as a first step, be treated as if affecting all commodities in the same way[32] by including an intercept (country-dummy) in every equation. But if, on the other hand, a commodity-specific regression model like (22) is preferred, such a treatment is not possible, and these determinants, if not explicitely modelled otherwise[33], may well lead to heteroscedastic disturbances in every equation and to nonzero covariances for different commodities and the same country in cross commodity applications of (22). In other words, what we have is an error components model, where the error term consists of a country component and a combined country-commodity component.[34] This, then, gives rise to the GLS estimator for the single commodity estimation of (22) or to ZELLNER's (1962) SURE estimator for simultaneous estimation of (22) for several commodities.

Analogous arguments can be developed for commodity-specific non-Heckscher-Ohlin determinants. One might, for instance, think of the well known fact that commodities differ in terms of their tradability, due to such things as bulkiness, and in terms of the size of

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32 This is, of course, a rather restrictive assumption. However, one might think of gravitation effects, as modelled by LINNEMANN (1966), of different levels of tariffs or non-tariff barriers in different countries, or of aggregate trade deficits determined by macroeconomic forces. Note, however that, because of the definition of a_j and g_j, dividing equation (2) by y_j-b_j, domestic absorption, leads to

$$x_{ij}/(y_j-b_j) = \Sigma_h \alpha_{ihj} \theta_{hi} (V_{hj}/(y_j-b_j) - V_{hw}/y_w) + u_{ij},$$

where V_{hj} is country j's endowment with factor h, expressed in value terms, and w indicates the whole world. Thus, all regression models above can be reformulated such that trade as well as endowments are "normalized" by the respective expenditures.

33 See, for instance, LEAMER (1974), where such determinants are modelled in the systematic part of the regression equation.

34 The error components model has primarily been discussed in the context of pooling time series and cross section data. For a brief discussion, see PINDYCK & RUBINFELD (1976, pp. 206-208) and PHILLIPS & WICKENS (1978, pp. 208-210).

the world market, due to preferences.[35] Again, these effects may, in a rudimentary way, be "modelled" through intercepts in cross commodity applications of equation (22). But if, for some reason, country-specific regressions like (21) are preferred, the consequences that these effects may have upon the disturbance term should be taken into account by choosing GLS estimators.[36] Alternatively, such problems can be avoided by using a binary dependent variable (0 for $x_{ij} < 0$ and 1 for $x_{ij} \geq 0$, say) and employing a suitable econometric technique such as LOGIT or PROBIT analysis.[37]

The above remarks show two ways of treating non-Heckscher-Ohlin determinants of trade in the interactional regression models (21) and (22). They can either be "modelled" in the systematic part of the equations by estimating intercepts, or they can be "modelled" in the stochastic part by an error components model. It should be emphasized that these two treatments are not equivalent. In particular, the latter assumes that the mean effect of these determinants is zero, whereas the former also allows nonzero means but does not

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35 Quite frequently, such arguments have lead to the use of BALASSA's (1965; 1977) RCA measure, where a commodity's export share for a given country is "normalized" by its share in world exports. But it is difficult to find a rigorous theoretical justification for the use of such a measure as the dependent variable in regression analysis. For a more detailed analysis of how "revealed" comparative advantage so defined can be related to trade theory, see HILLMAN (1980) and BOWEN (1983). Bowen's work is of special interest here, because he proposes an alternative measure of comparative advantage derived from considerations similar to those underlying the HOV model. Hence, it is not surprising that Bowen's index comes pretty close to the dependent variable of the above regressions. In terms of the present notation, Bowen's index is $x_{ij}/(y_j q_{iw}/y_w)$, where q_{iw} indicates world production of commodity i. According to BOWEN (1983, p.470), the advantage of this measure is "that scale effects due to both commodity and country size are removed". As for country size in the above regressions, see footnote 35 above, and adjusting for heteroscedasticity due to commodity size according to the text above may well lead to scaling the equation by a variable like q_{iw}. For a discussion of Bowen's proposal see BALLANCE, FORSTNER & MURRAY (1985; 1986) and BOWEN (1985; 1986). BOWDEN (1983, pp. 217-218) has also pointed out that employing Balassa's RCA index as a dependent variable would entail "addding up" restrictions, which would pose additional econometric problems.

36 In the empirical literature, the problem of heteroscedastic disturbances in regression equations like (21) has been treated by scaling down the whole equation by the square root of a variable, to which the variance of the error term was believed to be proportional, which is equivalent to using GLS. BRANSON & MONOYIOS (1977) and STERN & MASKUS (1981) use the square root of shipments. For the same reason, BALASSA (1986) uses gross trade (exports plus imports) to scale the dependent variable alone, but such a procedure leads to econometric problems because the dependent variable is restricted to values between -1 and 1. Moreover, an appropriate treatment of the heteroscedasticity problem requires scaling down the whole equation, not just the dependent variable (see also DEARDORFF, 1984, pp. 487-488).

37 See, for instance, HARKNESS & KYLE (1975), BRANSON & MONOYIOS (1977), BAUM & COE (1978), STERN & MASKUS (1981), and FORSTNER (1984). However, see also DEARDORFF's (1984, pp. 473-474) critique of this approach.

separately "model" the random deviations about this mean. The former, of course, also saves parameters and, hence, degrees of freedom. A maximum treatment of these non-Heckscher-Ohlin determinants would include intercepts and a threefold composite error term (commodity-, country- and combined error component).[38]

The interactional regression models (21) and (22) satisfy a fundamental prerequisite for an empirical examination of the factor proportions theory: They involve all of the three key concepts of that theory: factor intensities, factor endowments and trade. A large body of empirical work has been restricted to observing only two of these three concepts and has used the empirical results to infer the third. This, of course, amounts to assuming the validity of the factor proportions theory rather than examining it. The majority of these empirical studies has run regressions of trade on factor intensities[39], much less attempts have been made to regress trade on factor endowments[40]. Notwithstanding problems of specification that some of these studies may have from the point of view of the present paper[41], it can be seen quite easily, how these approaches relate to the above interactional regressions. Equation (21) and (22) can be rewritten as

$$x_j = \theta'\lambda_j + \mathbf{u}_j, \tag{23}$$

and

$$x_i = \mathbf{G}\mu_i + \mathbf{u}_i, \tag{24}$$

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38 See PHILLIPS & WICKENS (1978, pp. 209-210) for a two step procedure that allows an approximate empirical implementation of the GLS estimator in this case.

39 See, for instance, STERN (1976), BRANSON & MONOIYOS (1977), STERN & MASKUS (1981), MASKUS (1983), and URATA (1983).

40 See LEAMER (1974), BOWEN (1983), and LEAMER (1984).

41 Such problems may exist inasmuch as these studies deviate from the general formulations of the factor proportions theory presented here in the way they measure trade, factor intensities and factor endowments.

where $\mathbf{G}' = (\mathbf{g}_1, \mathbf{g}_2, \ldots, \mathbf{g}_m)$. The h-th element of λ_j is $g_{hj}\alpha_{hj}$, and the h-th element of μ_i is $\theta_{hi}\alpha_{ih}$.[42]
Thus, running a regression of trade on factor intensities as in (23) yields estimates of $g_{hj}\alpha_{hj}$. It is important to see that, for the factor proportions theory to receive empirical support, these estimates must be such that they can be "externally validated"[43] by actual observations of g_{hj}. This can either be done informally or formally, as in BALASSA (1979.a, 1979.b, 1986)[44] and BALASSA & BAUWENS (1985), by means of a second stage of regression analysis, in which the estimated coefficients obtained in the first stage are related to observed factor endowments.
By analogy, cross country regressions of trade on factor endowments for individual commodities as in (24) can be interpreted as yielding estimates of $\alpha_{ih}\theta_{hi}$. And whatever the degree of explanation achieved in such a regression, a test of the Heckscher-Ohlin theory requires that these estimates should somehow be confronted with independent observations on the "factor shares". Again, such an "external validation" can either be carried out informally or formally by means of a second stage of regression analysis.

It may be worth mentioning that equations (23) and (24) have identical regressors for different countries (given factor price equalization or Cobb-Douglas technologies) and different commodities, respectively. Hence, ZELLNER's (1962) SURE estimator simplifies to the OLS estimator. However, one may wish to apply a GLS estimation procedure in the second stage of "external validation" to give higher weights to factors with pronounced international endowment differences or to commodities with low standard errors of estimate in the regression (24).

This completes the discussion of regression analysis proper as a means of testing the commodity version of the Heckscher-Ohlin theory. It turned out that such an approach

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42 In empirical applications of (23) one should take care of the fact that the individual elements of every row of ' add up to one if the regressors are proper factor shares.

43 The term "external validation" goes back to LEAMER (1974). The concept of "external validation" is a general one and not restricted to the factor proportions approach. It can be applied to any trade theory that "views trade as the offspring of an economic marriage between product characteristics and national attributes" (HUFBAUER, 1970, p. 146). For a more general application, see HUFBAUER (1970), for an application to the technology theory of trade, see SOETE (1981).

44 BALASSA (1986) also applies the error components model briefly discussed above.

cannot be based on a rigorous derivation from the general versions of that theory. To some extent, one has to resort to intuitive steps in trying to parameterize the theory towards regression equations. Although tese steps could at least be made explicit, one might still wonder whether or not the situation could be improved somewhat by trying to use less general versions of the theory as the basis for empirical work, which allow a more rigorous derivation of regression-type hypotheses. The following chapter will briefly discuss recent examples of such an effort to achieve rigorosity at the expense of generality

4. INVOKING THE "EVEN" CASE

Apart from Balassa's work, SAXONHOUSE (1983) and LEAMER (1984) are, to date, the most important comprehensive studies of world trade flows trying to test the Heckscher-Ohlin theory in its commodity version by means of regression techniques. Whereas Balassa's work more or less follows the above modeling suggestions, the work of Saxonhouse and Leamer might be regarded as representing an approach "sui generis", warranting separate treatment here.[45]

As opposed to the approach outlined in the above chapter, Saxonhouse and Leamer do not try to use the full general theory in deriving their regression equations. Instead, they invoke the so-called "even" case, in which the number of goods equals the number of factors. This seems to allow a truly rigorous derivation of a Heckscher-Ohlin hypothesis testable in a regression framework. In the "even" case (1) ca be solved for t_j as

$$t_j = B^{-1}\{(1-a_j)f_j - a_j f_{jR}\}, \tag{25}$$

45 Actually, Saxonhouse does not try to test the Heckscher-Ohlin Theory, but, instead, assumes its validity to infer the role that trade barriers might play in the evolution of the Japanese trade structure. Moreover, instead of using the Vanek model, Saxonhouse uses parameterized versions of indirect utility and revenue functions.

and it is this linear dependence of trade on resource endowments that forms Saxonhouse's and Leamer's maintained hypothesis (SAXONHOUSE, 1983, p.291, and LEAMER, 1984, p. 59).

In practical terms, of course, Leamer has to start with a situation n > m. Hence, his Heckscher–Ohlin hypothesis proposes the existence of an aggregation of the n commodities to m aggregates, such that net exports in every aggregate accross countries can be explained in a linear fashion by weighted factor endowment differences.[46] There is no specific parametric hypothesis associated with this approach. Recall from the Dixit & Woodland result stated above that, unless there are only two commodities and factors, the "even" case still relies on arcane conditions for a specific sign structure of such partial derivatives, as represented by the coefficients in such a regression model. Basically, the theory receives its support from high R^2 values in the estimated equations. Leamer estimates these relationships using considerably refined econometric techniques in order to tackle various problems, such as heteroscedasticity, outliers in the sample, measurement errors and collinearity. The latter two are particularly noteworthy, as they are usually ignored.

However, what is of special interest here, is the empirical exercise of commodity aggregation, which is necessary before the "even" case can be invoked. Note that theory offers a "perfect aggregation matrix", **B**, which makes trade in the aggregates actually equal to endowment differences. Leamer never really observes this matrix, but by his choice of aggregation criteria he somehow implicitely aims at an aggregation matrix "close" to **B**. He groups together commodities a) with a high cross–country correlation of net exports and b) with similar regression coefficients as obtained in cross–country regressions of net exports on factor endowments (LEAMER, 1984, p. 60). Using the latter criterion to some extent already secures the good results in the aggregate regression equations. Furthermore, being able to separate different aggregates in terms of industry characteristics like factor intensities (pp. 66 – 73) is what links his aggregation matrix to the matrix **B**. This feature of his aggregation is crucial for the support that his results render for the factor proportions theory, and it makes his analysis somewhat similar to the above "external validation" approach.

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46 See also ANDERSON's (1987) review of Leamer's book.

This suggests that invoking the "even" case does not really solve the problem of having to rely on intuitive steps to link ones regression analysis to the factor proportions theory. All that happens is a shift of the intuitive steps into the pre-regression exercise of commodity aggregation, and it is quite obvious that trying to achieve a "good" aggregation involves considerations similar to the ones suggested in the previous chapter.

Saxonhouse does not try to aggregate commodities to arrive at the "even" case with his data. Instead he supposes the existence of a great number of unobserved factors, and assumes that they are orthogonal to the ones actually observed. In practical terms, this again brings us to the approach outlined in the previous chapter.

5. CONCLUDING REMARKS

Whatever the orthodoxy of future trade theory will be, the interaction of factor intensities and factor endowments will, in all probability, continue to play an important role in the way that trade theory views the evolution of comparative advantage.

Similarly, regression analysis will probably continue to be a preferred method for conducting empirical research in international trade and in testing trade theories.

To the extent that this is true, the questions addressed in the present paper will continue to be important issues.

While the intuitive content of a theoretical approach, like that of the factor proportions theory, may be sufficiently simple to warrant an intuitive specification of a regression equation, the diversity of specifications to be found in existing empirical literature on the factor proportions approach and the associated problems of finding unanimous conclusions from this literature demonstrate the importance of thinking about how regression models might be linked to rigorous formulations of the thoery. And that is what I have tried to do in the present paper.

It has turned out that there are essentially two ways of linking regression analysis to the factor proportions theory.

The first is to transform available general formulations of the theory, such that the restrictions on the variables appear as restrictions on specific "estimators" of certain regression models. Essentially, this is a nonparametric, or descriptive, use of regression analysis, and it is only through specific "estimators" that a regression equation can be linked to theory in this case. In principle, there are various ways, in which regression analyses can firmly be linked to rigorous theory along these lines. But it was pointed out that regression studies, if derived in such a way, offer little or no advantage over direct empirical calculations of the factor content of trade and/or various correlations proposed by the theory. They are logically equivalent to the latter and constitute nothing but an observational detour.

The second is to parameterize the theoretical relationships such that regression analysis proper can be applied. As opposed to the nonparametric use of regression analysis, this requires some intuitive steps to be taken in order to obtain an estimable regression model. On the other hand, such an approach has the important advantage of opening up ways to combine the factor proportions theory with other trade theories in empirical research, either by extending the systematic part of the regression model or by taking account of certain properties of the error terms, as implied by these other theories, through the choice of appropriate estimation techniques.

Looking at the well known study by LEAMER (1984), I have also discussed, whether or not restricting oneself to the special case of an equal number of commodities and factors might be of any help to more rigorously derive a Heckscher–Ohlin hypothesis testable in a regression framework. The problem here is that such an approach will always involve a rather delicate empirical exercise of aggregation, which, in practical terms, is likely to come pretty close to the intuitive steps that may be used to arrive at a parameterization of the general theory.

One may finally want to ask to what extent, and how, the regression specifications to be found in the existing empirical literature on the factor proportions approach diverge from the main thrust of the present paper. The paper closes with a few general remarks on this question.

First, it is quite clear from the above analysis that net commodity exports should be used as the dependent variable. Much of what has been said in favour of other measures in respective discussions in the literature finds its way through to certain properties of the disturbance terms and can, accordingly, be adequtely treated by appropriate estimation techniques.

Secondly, factor intensities should be defined to be "factor shares" rather than factor input ratios as used in the traditional two by two case.[47]

Thirdly, weighted factor endowment differences instead of factor endowment ratios should be used to measure international factor abundance.[48]

It is probably safe to say that the diversity of different regression specifications to be found in the empirical literature and the associated problems of interpretation would hardly be conceivable, if more emphasis had been put on the link between the regression equations used and rigorous formulations of the factor proportions theory.

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47 The use of "factor shares" to measure factor intens
it avoids problems of indeterminacy in factor inten
factors.
Factor input ratios have been used as regressors b
AMSDEN (1980), OHLSON (1980), HULSMAN VEJSOVA [illegible] & BAUWENS
(1985), and BALASSA (1986).
URATA (1983), MASKUS (1983), STERN & MASKUS (1981), and BRANSON & MONOYIOS (1977) use absolute factor inputs, which are then scaled by the sqare root of shipments along with the dependent variable to account for heteroscedasticity.

48 In some cases per capita - GDP has been used instead of the capital/labour endowment ratio (BOWEN, 1983; BALDWIN, 1979; and BALASSA, 1979.a, 1979.b). It is interesting to note that BALASSA & BAUWENS (1985, pp. 6-7) obtained better results using factor endowment differences than using factor endowment ratios.

APPENDIX

Equation (2) :

Suppose there are only two countries, country j and country l. Due to identical and homothetic tastes, in free trade equilibrium we must have

$$\mathbf{q}_j = \mathbf{t}_j + a_j \mathbf{q}_W, \qquad \text{(A.1)}$$

where $\mathbf{q}_W$ is the world production vector and a_j is the share of country j's absorption in world–GDP. Full employment means

$$\mathbf{B}_j \mathbf{q}_j = \mathbf{f}_j. \qquad \text{(A.2)}$$

This gives

$$\mathbf{B}_j(\mathbf{t}_j/a_j + \mathbf{q}_W) = \mathbf{f}_j/a_j. \qquad \text{(A.3)}$$

An analogous expression hold for the second country l, with $\mathbf{t}_j = -\mathbf{t}_l$, which can be subtracted from (A.3) to yield

$$(\mathbf{B}_j/a_j + \mathbf{B}_l/a_l)\mathbf{t}_j = \mathbf{f}_j/a_j - \mathbf{f}_l/a_l - (\mathbf{B}_j - \mathbf{B}_l)\mathbf{q}_W, \qquad \text{(A.4)}$$

which gives equation (2) of the text above, if multiplied by $a_j a_l$.

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