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FACTOR PRICES AND THE FACTOR CONTENT OF TRADE REVISITED:

WHAT'S THE USE?

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August 8, 1997

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ABSTRACT

Factor Prices and the Factor Content of Trade Revisited: What's the Use?

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This paper examines the usefulness of a result of Deardorff and Staiger (1988), who showed that the factor content of trade can be interpreted under certain assumptions as indicating the nature of the factor price adjustments that can, in a specified sense, be attributed to that trade. This paper elaborates on the sense in which this result says anything about the factor market effects of trade. It also examines several of the assumptions that were used by Deardorff and Staiger to determine whether they can be relaxed. These include the assumption, used for only one of Deardorff and Staiger's several results, of Cobb-Douglas technology, which is shown to be easily extended to Constant Elasticity of Substitution. Also examined is the assumption of nonspecialization, or that all imported goods are produced or producable in the domestic economy. With Cobb-Douglas technology that assumption is shown not to be needed. With more general technology, however, the presence of non-competing imports requires a reinterpretation of the factor content of trade. Whereas without noncompeting imports, trade itself is analogous, in terms of its effects on factor markets, to a change in factor endowments equal to the factor content of trade, with noncompeting imports trade has an additional effect analogous to a Hicks-neutral technological improvement enabling those noncompeting imports to be produced competitively.

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I. Introduction

A few years ago, Bob Staiger and I, in Deardorff and Staiger (1988) (D-S), derived some curious little results from versions of a generalized Heckscher-Ohlin (H-O) trade model concerning the relationship between the factor content of trade and associated changes in factor prices. A few years later, first several labor economists, then trade economists, began to try to account empirically for the 1980s rise in the relative wage of skilled labor compared to unskilled labor in the United States. They paid particular attention initially to the possibility that changes in trade or trade policy might explain this rise, along the lines of the Stolper-Samuelson Theorem. One technique was to measure the skilled and unskilled labor embodied in the trade – its factor content – and then compare this to quantities in the relevant factor markets. Only after this technique, which was used first by labor economists, was criticized by trade economists as having no theoretical basis, was it noticed that the D-S result did in fact provide such a rationale.

However, Ed Leamer (1996) has disagreed, arguing that the D-S result was almost completely useless for this purpose. I will suggest that he spoke too soon. I agree that the D-S result should be used only with care and that some writers have gone way too far in using factor content to infer factor-market "effects" of trade when the true culprit could easily lie elsewhere, and I have tried to say as much in Deardorff and Hakura (1995). But

Leamer's objections to the assumptions needed for factor content to be meaningful can easily be addressed, and I do so here.

I will review the D-S results in Section II, emphasizing what I agree are their limitations. However, these limitations do not include, in my view, three assumptions that Leamer originally identified as needed for their validity: balanced trade, Cobb-Douglas technology, and nonspecialization. I dispense with balanced trade also in Section II, since it was not in fact used in the D-S derivations, although our handling of that issue was evidently unclear. In Section III I turn to the Cobb-Douglas assumption that we used for our strongest result: an explicit solution of a model for factor prices in terms of the factor content of trade. This can easily be generalized to a constant-elasticity-of-substitution (CES) technology with a common elasticity of substitution for all production and consumption. Leamer may not like this much better, but I suspect that some readers will find this to be an improvement.

In Section IV I address what I regard as the more serious problem, the assumption of non-specialization. Since in other work of my own I have often stressed the importance of the alternative H-O case of specialization and the absence of factor price equalization (FPE), which I believe to be a better approximation to global reality than FPE, I too have been concerned that the factor content of trade might be of little use in reality for this and other purposes. Indeed, I have wondered why others were so willing to assume FPE in tests of the Heckscher-Ohlin Theorem using the Heckscher-Ohlin-Vanek version of it, as in Bowen, Leamer and Sveikauskas (1987).

Indeed, it turns out that with general technology the presence of non-competing imports does require a reinterpretation of the factor content of trade. As discussed in

Section II, without noncompeting imports trade itself is analogous, in terms of its effects on factor markets, to a change in factor endowments equal to the factor content of trade. However, with noncompeting imports trade has an additional effect that is analogous to a set of Hicks-neutral technological improvements enabling those noncompeting imports to be produced competitively at home. Since Hicks-neutral technological differences do not affect factor prices in a Cobb-Douglas world, it follows that the strong Cobb-Douglas result of D-S is valid after all with noncompeting imports. However, in other cases, including the CES case of Section III, inferences about factor markets from trade must take into account this additional and somewhat more complex effect of trade. In Section IV I first verify the relative-factor-price neutrality of Hicks neutral changes in technology, then examine what can be said about their effects with CES technology.

II. Factor Content and Factor Prices Revisited

The D-S results all grew out of the following observation: Under standard assumptions of the H-O model plus nonspecialization, it is possible to reproduce any trading equilibrium for a country as an autarky equilibrium by simply changing the factor endowments of the country by the amounts of the factor content of trade, adding those factors that were net imported through trade and subtracting those that were net exported. It follows that any comparison between two trading equilibria can also be made between their two equivalent autarky equilibria. Therefore in particular, differences in factor prices between two trading equilibria that may in some sense be associated with differences in their trade can be inferred from the differences in factor prices that would arise in autarky from differences in factor endowments. This result can be useful to the

extent that factor prices are systematically related to factor endowments. In D-S (1988) we derived one such very strong relationship for Cobb-Douglas technologies and preferences, a result that I extend below to CES technologies. We also derived a weaker correlation result for more general technologies.

One of Leamer's objections to the use of this result I strongly share. In comparing two trading equilibria of a country, there are many reasons why the quantities traded, and therefore the factor content of trade, may differ. To interpret a change in trade as some sort of outside force affecting a country is usually incorrect, and therefore to associate any changes in factor prices that may go with it as being caused by it is also incorrect. The changes in U.S. trade that occurred in the 1980s, for example, were undoubtedly the result of a whole host of causes, both internal and external to the U.S. Using the factor content of these changes in trade to infer what changes in factor markets were "due to" trade mistakenly attributes causation to trade, when it in fact was being caused to change by other forces.

Furthermore, as should be clear from the method of proving the D-S result just described, it is only true that factor content can be related to factor markets if we can hold other things constant, including domestic technologies, preferences, and factor endowments. Therefore, if any of these things were to have changed during the period of a change in trade that is being analyzed, perhaps even as their cause, the effects of these other changes on factor markets will not be captured by the factor content of trade. Therefore, only if trade has changed due entirely to forces other than these, such as changes in trade policy at home or abroad or changes only within the foreign economies,

may the factor content of trade, together with the D-S result, tell us something about the effects of those changes on domestic factor markets.

This does not, however, mean that the result has no meaning. Even for changes in trade that are caused by changes in domestic technology or other things held constant in the result, there remains an interpretation of the factor content of trade that is valid. Suppose that quantities of trade change for any reason. We may ask by how much factor prices would have changed differently if the changes in trade had been prevented by changes in domestic trade policy, and the D-S results give the answer. Thus regardless of whether actual changes in trade have been due to, say, reductions in tariffs, we may still ask how the economy would have fared differently had these changes been prevented by trade policy. If the changes actually *were* due to trade liberalization, then we will have captured the effects of that liberalization. But if they were due to any other causes, we will not have captured the factor market effects of those causes. Rather, we will have measured the factor market effects of accompanying those causes, whatever they may be, with trade policies to insulate any effects on quantities traded. Thus the factor content of trade does help us to answer a question. Whether it is one that anybody is asking is another matter.

Leamer objected that our result depended on trade being balanced. That is not the case, as we mentioned in a footnote. However, it may be useful to work through why this is true and what the meaning of the result is in the context of a changing imbalance of trade, as a way of illustrating what the result can and cannot say.

Suppose then that what has truly happened is that a small country has increased its expenditure on all goods, including both traded and nontraded, above its income,

financing the excess by borrowing from abroad. As discussed in Deardorff and Hakura (1995), since additional nontraded goods cannot be imported, the country's resources will shift into producing more nontraded goods, and these resources will be withdrawn from the traded sectors. It will therefore export less of its previous exports and import more of its previous imports, thus running the trade deficit that its increased expenditure makes inevitable.

The factor content of trade will also show this deficit, the country now importing more of some or all factors than it exports. Depending on the factor requirements of the traded goods, the factor content of trade may be suggestive of a change in relative factor prices according to the D-S result. But in fact, *factor prices have not changed at all*, as we know from FPE, so what can be the meaning of this result? The answer is this: these are the changes in factor prices that *would have occurred* if the increase in expenditure had been accompanied by, say, increased import tariffs and export subsidies sufficient to prevent any change at all in the quantities of trade. Of course, had the increase in expenditure been accompanied by such policies, domestic prices would have changed and we would indeed have seen changes in factor prices. The factor content of trade turns out to be a tool for inferring what these changes would have been.

III. A CES Specification

I turn now to an extension of the strongest D-S result. This was a simple formula relating factor prices and the factor content of trade under the assumption that all production functions as well as preferences are Cobb-Douglas. Specifically,

D-S Proposition 2. If a country's preferences and technologies are Cobb-Douglas and identical in two trading equilibria for which factor endowments are also identical, then if prices are normalized to equate total expenditure to unity in both equilibria, then

$$\frac{w_i^2 - w_i^1}{w_i^1} = \frac{S_i^2 - S_i^1}{B_i^2}$$

for every factor i. Here, w is the price of the factor, S is the net amount of that factor embodied in the country's trade, and B is the amount of that factor embodied in consumption (assumed equal to final demand).

The rationale for this result is simply that factor prices depend in autarky on supply and demand for factors, and with Cobb-Douglas technologies and preferences, the economy is equivalent to one in which factors are demanded directly for consumption, also with Cobb-Douglas preferences. Thus with appropriate normalization the demand for factors has unit elasticity, and demand can be inverted to yield equilibrium factor prices that also depend unit-elastically on factor quantities. Not surprisingly, perhaps, a world of common-elasticity CES technologies and preferences will be almost equally well-behaved.

Suppose, then, an autarkic, representative-consumer economy in which goods $x_j,\ j = 1,\ldots,n$ are consumed and enter a CES utility function,

$$U = \left(\sum_j a_j x_j^\rho \right)^{\frac{1}{\rho}} \tag{1}$$

where $a_j > 0$ are parameters determining (but not equal to) expenditure shares and ρ is related to the elasticity of substitution, $\sigma > 0,\ \rho = \frac{\sigma - 1}{\sigma} < 1$. Goods are produced from m factors, i, also with CES production functions with elasticity σ:

$$x_j = \left(\sum_i b_{ij} v_{ij}^\rho \right)^{\frac{1}{\rho}} \tag{2}$$

where v_{ij} is the amount of factor *i* used in producing good *j*, and $b_{ij} \geq 0$ are parameters that permit arbitrary (but non-reversing, since industries share identical elasticities of substitution) factor intensities.

Define total demand for a factor, v_i, as

$$\sum_j v_{ij} = v_i , \tag{3}$$

and define national income, *Y*, as

$$\sum_i w_i v_i = Y . \tag{4}$$

By choosing x_j, v_{ij}, and v_i to maximize (1) for given w_i and *Y*, we can derive demands for factors that can in turn be equated to their supplies to derive equilibrium factor prices.

Substituting (2) into (1) and (3) into (4), the maximization problem becomes one of selecting factor inputs only:

$$\max_{v_{ij}} U = \left[\sum_j \sum_i c_{ij} v_{ij}^{\rho} \right]^{\frac{1}{\rho}} \quad \text{where } c_{ij} = b_{ij} a_j \tag{5}$$

$$\text{subj. to} \quad \sum_i \sum_j w_i v_{ij} = Y \tag{6}$$

This is a conventional CES demand problem, and the solution is equally conventional:

$$v_{ij} = \frac{Y}{w_i} \left(\frac{c_{ij}^{\frac{\sigma}{1-\sigma}} w_i}{\left[\sum_{i'} \sum_{j'} c_{i'j'}^{\sigma} w_{i'}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}} \right)^{1-\sigma} . \tag{7}$$

That is, demand for a factor input departs from the Cobb-Douglas case (Y / w_i) by a term comparing the wage of factor *i* to a CES index of the wages of it and all other factors. Defining that index as

$$I = \left[\sum_i \sum_j c_{ij}^{\sigma} w_i^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{8}$$

we can sum the v_{ij} to get total factor demands

$$v_i = \sum_i v_{ij} = C_i \frac{Y}{w_i} \left(\frac{w_i}{I} \right)^{1-\sigma} \tag{9}$$

where

$$C_i = \sum_j c_{ij}^{\sigma} . \tag{10}$$

If we now also normalize factor prices so that *I*=1, then factor demands depend very simply on their respective factor prices:

$$v_i = C_i Y w_i^{-\sigma} . \tag{11}$$

In equilibrium these factor demands must equal factor supplies, $\bar{v}_i$, and we can solve for equilibrium factor prices, $\tilde{w}_i$, as

$$\tilde{w}_i = \left(\frac{\bar{v}_i}{C_i Y} \right)^{\frac{1}{-\sigma}} . \tag{12}$$

Thus, in a CES world, autarky factor prices vary with respect to factor endowments with an elasticity $-1/\sigma$. It follows, using the same argument as in D-S, that factor prices in different trading equilibria with different factor contents of trade but identical preferences, technologies, and factor endowments will display an elasticity $-1/\sigma$ with respect to the factor content of trade relative to endowments. Thus the Cobb-

Douglas case of D-S was special, but not unique in permitting a strong relationship between factor prices and factor content of trade.

Of course, even this CES world is very special, since I have assumed the same elasticity of substitution in all production and utility functions. Without that, things would not be nearly so simple, and probably not worth working out in tedious detail. However, the general point is that an autarky economy behaves like a consumer indirectly demanding factors for input to a utility function, and the resulting quantities of factors demanded must depend on factor prices in conventional ways. It follows that the equilibrium factor prices must also depend, in conventional but perhaps very complex ways, on factor quantities, and therefore that these factor prices are also related to the factor content of trade.

IV. Noncompeting Imports

The D-S result depends heavily on the assumption that all imports are capable of being competitively produced within the country. With that assumption, the factors that would be needed to produce them (their factor content), if they were added to the country's endowments, would not only make it possible to produce them at home with available factors and without changing other outputs. It would also, under the other usual Heckscher-Ohlin assumptions, cause that additional production to be an equilibrium outcome.

Noncompeting imports interfere with that reasoning. Suppose that some imports cannot be produced at home with the available technology and at existing factor prices without making a loss. That is the factors needed to produce a dollar's worth of these

imports cost more than a dollar. Then if we interpret that bundle of factors as the factor content of those imports and imagine adding them to the country's endowment, while it will become physically possible to produce them, that production will not happen in a competitive non-distorted economy. The factor content of those imports, if added to endowments, would be used for something else.

Of course it is unlikely that there is now only one possible definition of factor content. Unless there are distortions elsewhere in the world, the imports are almost certainly actually being produced with a different bundle of factors than would be used domestically. The foreign producers may be using less of all factors due to a superior technology, or they may just be using a different factor mix that costs less for them, though it would not for us, because factor prices are unequal. Either way, we could use that different bundle of factors to measure the factor content of the imports, but that would not help. Those factors either would not be sufficient to replace the imports with domestic technology, or they could do so but not at minimum cost.

In short, as far as I can see, there is no definition of the factor content of trade that we can apply to noncompeting imports that will allow us to replicate in autarky all other aspects of a trading equilibrium and thus move on to the other D-S results. That is one of Leamer's (1996) major criticisms, and I take it to heart. There are many trade economists who often seem more than willing to assume a world of complete factor price equalization, all the world in a single diversification cone, where noncompeting imports do not exist. But I have always felt that FPE provides a poor approximation to the world of many diverse countries in which we live, and if asked to choose between FPE and, say,

a world of two diversification cones and sets of factor prices as my favorite false model of the world economy, I would choose the latter. In that world, the D-S result does not hold.

Let me suggest, however, a simple alternative result that does hold. Suppose as our experiment we imagine changing not just factor endowments but also technology in constructing our equivalent autarky equilibrium. That is, suppose that instead of imports we give a country a Hicks-neutral technological improvement sufficient for it to break even producing the imports, and then also, as before, give it the factors needed to produce the imports with that technology. Now, as in the case of only competing imports, we are able to reproduce the trading equilibrium with an equivalent autarky equilibrium. And when we move from one trading equilibrium to another with both different factor content of trade and possibly with different noncompeting imports, that will be equivalent to a combined change in both factor endowments and technology. To the extent that we can infer factor price changes from these two exogenous changes in autarky, then we will also be able to infer factor price changes from changes in factor content of trade together with some information about noncompeting imports.

This may seem an awkward and pointless exercise, but I will suggest that it is not. First, just thinking about trade in this way reminds us of something that we have long known, but often forget. In a general Heckscher-Ohlin world and even beyond, trade along the lines of comparative advantage serves two purposes. It allows a country to consume what it has not the factor endowments to produce, and also what it has not the technology to produce itself. Imports, therefore, are equivalent not only to proxy factor inputs but also to proxy technology as well, or at least that is the case when those imports are noncompeting.

When discussing the gains from trade, many of us fondly quote Ingram's parable of a new and wildly popular technology that turns out to be just international trade, and we use it to explain why the welfare effects of trade are no less desirable than the welfare effects of technological improvement. But the parable extends beyond just the gains from trade to all other effects of trade as well, including the effects on factor prices. Recognizing that imports are equivalent to a combined transfer of both factors and technology helps to remind us of that fact.

The next question is whether this does us any good. The surprising answer is yes, a great deal, at least in one special case. Consider the effects of a Hicks-neutral technological change in a Cobb-Douglas economy of the sort underlying D-S's Proposition 2. In such an economy, each factor's share of national income is fixed, and will not change in response to any and all Hicks-neutral changes in preferences or technology. All factors will gain, of course, but if factor endowments do not change they must gain in the same proportion.

So it turns out that D-S Proposition 2 is valid after all, even in the presence of noncompeting imports. The reason is that now trade is equivalent to a combination of a change in autarky factor endowments equal to the factor content of trade together with a set of Hicks-neutral technological improvements that would make it efficient to produce all noncompeting imports at domestic factor prices. The equivalent change in endowments has the effects on factor prices given by D-S Proposition 2, while the technological improvement causes no further change in relative factor prices. The argument also clarifies how factor content of noncompeting imports should be measured:

as the least-cost factors needed to produce them at domestic factor prices *after* a Hicks-neutral improvement makes them competitive.

What if we do not have Cobb-Douglas technologies? Then the noncompeting imports really do matter, and in ways that could get rather complicated. But they are not hard to understand, and not necessarily hard to deal with. I will consider only a simple case for illustration.

Suppose the CES world that was discussed in Section III, and suppose only a single noncompeting import, *X*. What are the effects on factor markets of a Hicks-neutral technological improvement for producing *X*? The improvement will make *X* cheaper, and increase demand for it. But whether expenditure on it (and on the factors to produce it) will expand on contract depends on the elasticity of substitution, σ. If substitution is elastic, $\sigma > 1$, then demand for the good will expand more than price has fallen, expenditure will rise, and that increased expenditure will be passed through to the markets for whatever factors the good employs, altering their prices as well. If substitution is inelastic, the reverse will hold. Only if the elasticity is one, the Cobb-Douglas case already mentioned, will there be no effect on factor markets.

Therefore, for example, if we wish to compare factor prices in two trading equilibria that differ in their factor content of trade and also in the presence of a new noncompeting import, *X*, in the new equilibrium, then in addition to the effects of factor content that we explored in Section III, we should also account for the technological improvement that the new noncompeting import represents. For example, if $\sigma > 1$ and *X* is, say, skill intensive, then we expect a larger increase in the relative wage of skilled labor than we would have predicted based on factor content alone.

There are also a number of cases, in addition to the Cobb-Douglas case, where we do not have to do anything. If our two trading equilibria do have noncompeting imports but they are the same ones, and if the size of cost reduction needed to make them competitive is unchanged, then they do not matter for relative factor prices. Or, if there are many changes in noncompeting imports but their average factor intensity is the same as that of the economy as a whole, then again we can ignore them since their effects will cancel out.

This is not to say that these cases are at all likely, however. To take perhaps the simplest and most basic example from the Heckscher-Ohlin model, consider the effect of trade (as compared to autarky) on factor prices for a small two-sector economy that is completely specialized in the skill-intensive good. The unskill-intensive good is its noncompeting import. If we were to measure its factor content of trade we would find, of course, that it exports skill and imports unskill, and we might use the D-S result to infer (correctly, in terms of sign) that trade has lowered the relative wage of unskilled labor compared to autarky. If this is a CES economy with elasticity, say, three, we might even use the result of Section III to calculate the size of this decline by measuring the factor content, comparing it to endowments, and using the elasticity 1/3. But because of the noncompeting import, this would be wrong. The noncompeting import of the unskill-intensive good has also had the effect of a Hicks-neutral technological improvement in producing it, of a size that depends on just how cheap it is on the world market. Since demand is elastic, that improvement corresponds to an increase in demand for unskilled labor along with the increase in supply represented by its factor content. Therefore the appropriate price of unskilled labor should be higher. In this case, the presence of the

noncompeting import has caused us to overstate the change in factor prices using just the factor content of trade.

V. Conclusion

Is the factor content of trade of any use? I think so. It must be used with careful attention to both the questions that answers, and to the assumptions needed for it to provide correct answers. These assumptions are not trivial, but they are not quite as special as may be alleged, and one can understand and deal with the biases that departures from these assumption entail.

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