A Modification of Ronald Jones's Specific Factors Model; with Historical and other Applications

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ABSTRACT

Jones (1971) examines a three-factor two-good model under the assumption that two of the factors are specific to one sector (a different sector for each such factor). In this paper that specification is weakened, so that only one sector (agriculture) has a specific factor (land). When land is a separable input into food production, factor price-equalization can no longer be shown, but Stolper-Samuelson magnification is still observed, although it is weakened. Applications to the abolition of the Corn-Laws and to North-South trade are discussed.

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> "With three or more factors of production it is certainly not necessary that the result of trade is to make the ratios of factor prices in the respective countries more closely approach unity. Some may do so, but others may diverge depending upon complicated patterns of complementarity and competitiveness." (Stolper and Samuelson 1941-2, p. 72)

1.1. Introduction

The Heckscher-Ohlin-Samuelson (HOS) 2X2 trade model has stood up well to heavy usage over many years. Its popularity is explained by the ease with which it may be applied to answer many different questions, and by its great intuitive accessability. A model which was forged to explain the pattern of trade between the old and new worlds in the nineteenth centuries; and can be readily developed to treat the question of why unions favour protection, the effect of migration on production patterns, and many other questions, is surely a well-made model. Yet nearly everyone who has been exposed to the model has felt some worries and dissatisfaction. Which precisely are the two goods? Which are the two factors? Close behind those questions of economic relevance comes a natural mathematicians enquiry. Are these essentially 2X2 results; or are there higher dimension versions of the same theorems?

Broadly speaking the news from the higher dimension front is discouraging. Crucially the concept of unambiguous relative factor intensity, which is a foundation stone of the HOS model, cannot be interpreted in high dimension theory. If the numbers of factors and goods are assumed to be the same - a strange feature in a high-dimension world - and diagonal dominance, or some similarly highly re-

strictive property is assumed, it may again be possible to associate the production of individual goods with the employment of particular factors. But this is more special even than the simple factor intensity assumption of the base HOS model.

In any case, going beyond 2X2 forces the issue of squareness versus non-squareness. Should the number of factors and goods be expanded in parallel, so that the two values remain equal? A 3X2 model differs from a 2X2 model in a different way from that which separates a 2X2 model from a 3X3 model. Ethier (1984) provides an excellent survey of this eclectic field. For the most part Ethier neglects what may be called toy models. By a toy model I mean a simple low dimension model built for a particular purpose, without any pretensions to mathematical generality. One might say that the HOS model started as a toy model in that sense, but so much has it become the reference model of trade theorizing that it is hard to see it today as the toy model which it was originally.

The paper is structured as follows. Section 2 explains the Jones model. Section 3 introduces a generalization of that model in which only one sector has a factor used alone in that sector, including a simple version of the extension in which the third factor enters as a separable input into production. This model is called the GTFM. Section 4 investigates what can be said when separability is not assumed. Section 5 shows what can said of the slope of the factor-price frontier in the GTFM; an important comparative issue, as it is a central point with the Jones model. Section 6 applies the model to the abolition of the Corn Laws in Britain in the 1840s. Section 7 applies the model to North-South trade as discussed by Wood (1994). Section 8 concludes.

1.2. The Jones Toy Model

Jones (1971) is a root source for what later came to be called the specific factors model. Jones examines a three-factor two-good model under the assumption that

two of the factors are specific to one sector (a different sector for each such factor). There is an important difference between what Jones assumed and the view taken typically by later writers on the specific factors model. Jones supposed that two of the factors are permanently wedded to their two separate sectors. Most later expositions of the model suppose that the long-run equilibrium is that described by the 2X2 HOS model. However following a shock the immobile factor (often taken to be capital) is misallocated between the two sectors. Then the specific quantities of immobile capital can be taken temporarily to be entirely different factors, exactly as Jones assumes.

Thus the two different specifications imply exactly the same model in the very short-run. All this is made abundantly clear in the survey by Jones and Neary (1984). For our present purposes it is helpful to stay with the original Jones specification. So the factors specific to certain sectors are permanently confined to those sectors. Their imprisonment in one sector is not the result of short-run immobility: they can never be productive elsewhere. In this model factor-price equalization does not feature, not even in the long-run. Also, as with the short-run equilibrium of any specific factors model, Stolper-Samuelson magnification cannot be shown.

The historical question to which Jones applies his model is inspired by Peter Temin - see Temin (1966). Temin reported that relative to the US at the same time, Britain in the mid-Nineteenth century appears to have had a lower wage rate and a lower rate of profit.. If both countries have the same technology, an assumption that Temin felt unable to dismiss, a standard 2X2 model, with two factors, capital and labour, would not permit that outcome. There would be a common factor-price frontier, valid for all countires with the same technology. That would entail that a lower wage rate would have to imply a higher rate of profit.

Jones shows that his 2X3 model does not lead to a negatively-sloped relationship between the rate of profit and the wage rate. We can interpret the model as follows. The specific factors are unskilled labour and capital. The mobile factor is skilled labour (ingenious Yankees); a factor with which the US is relatively well endowed. The equations of the model are:

$$c_a\left[w,s\right]=1 \tag{1}$$

$$c_m\left[r,s\right]=p \tag{2}$$

$$y_m\cdot\frac{\partial c_m\left[r,s\right]}{\partial r}=K_0 \tag{3}$$

$$y_a\cdot\frac{\partial c_a\left[w,s\right]}{\partial w}=L_0 \tag{4}$$

$$y_a\cdot\frac{\partial c_a\left[w,s\right]}{\partial s}+y_m\cdot\frac{\partial c_m\left[w,s\right]}{\partial s}=S_0 \tag{5}$$

where p is the price of manufactures in terms of the agricultural good, $c_j\left[\cdot,s\right]$ is the unit cost function for sector j (j=a or m); that is agriculture or manufacturing); r , w and s are the factor prices in terms of agricultural output of respectively capital, unskilled labour and skilled labour; y_j is output in sector j; and K_0, L_0, and S_0, are given factor supplies of respectively capital, unskilled labour and skilled labour.

Eliminating s from equations (1) and (2) gives an implicit functional relationship between w and r. Differentiating totally with respect to w gives:

$$\frac{\partial c_a\left[w,s\right]}{\partial w}+\frac{\partial c_a\left[w,s\right]}{\partial s}\frac{ds}{dw}=0 \tag{6}$$

$$\frac{\partial c_m[r,s]}{\partial r}\frac{dr}{dw}+\frac{\partial c_m[r,s]}{\partial s}\frac{ds}{dw}=0 \tag{7}$$

The partial derivatives in (6) and (7) are unit factor input coefficients. Hence:

$$\frac{a_u^a}{a_s^a}=\frac{a_c^m}{a_s^m}\cdot\frac{dr}{dw} \tag{8}$$

where a_j^i is the unit input of factor j ($j=c,s$ or u) into sector i ($i=a$ or m). From (8), $\frac{dr}{dw}>0$. The "factor-price frontier" slopes upwards.

1.3. Another Toy Model

The model is:

$$c_a[r,w,q]=1 \tag{9}$$

$$c_m[r,w]=p \tag{10}$$

$$y_a\cdot\frac{\partial c_a[r,w,q]}{\partial r}+y_m\cdot\frac{\partial c_m[r,w,q]}{\partial r}=K_0 \tag{11}$$

$$y_a\cdot\frac{\partial c_a[r,w,q]}{\partial w}+y_m\cdot\frac{\partial c_m[r,w,q]}{\partial w}=L_0 \tag{12}$$

$$y_a\cdot\frac{\partial c_a[r,w,q]}{\partial q}=N_0 \tag{13}$$

where $c_j[r,w,q]$ is the unit cost function for sector j (j=a or m), that is agriculture or manufacturing); r , w and q are the factor prices in terms of agricultural output of respectively capital, labour and land; y_j is output in sector j; and K_0, L_0, and N_0, are given factor supplies of respectively capital, labour and land. Equations (1)-(5) define a model which will be called the *General Three-Factor Model* (GTFM).

The use of the term General in the title of the model is only to distinguish it from a yet more special case to be examined shortly. That comparison apart, the model is not general in a wider sense. In fact it assumes and exploits a special and particular structure, in that one of the factors is used in only one sector.

A particular version of the GTFM was created by the author to analyse the economic consequences of the abolition of the Corn Laws, see Bliss (1998). Here it is germane to note why neither a completely general three-factor two-goods model, nor Jones' model is suitable for that particular application.

The completely general model cannot be terrible, as it is most general. Yet by including land as an input to manufacturing the analysis is complicated greatly to no good purpose. While factories do have to stand on some land, the input level involved is trivial compared with agriculture, which necessarily uses land on a large scale. On the other hand the equivalent of Jones' assumptions would force us to suppose that no capital is used in agriculture, and that would make it impossible to engage with contemporary debates that plainly suppose the opposite to be the case. For instance an argument commonly used by landlords and their allies to defend agricultural protection claimed that they deserved compensation for the capital which they had expended to improve their land. Whatever one makes of that argument, it cannot be seriously addressed with a model which assumes that no capital could be used in agriculture.

The GTFM can behave in a manner easily comparable with an ordinary HOS model. To see this, suppose that the production function for agricultural output is a constant returns function of the form:

$$y_a = \phi^a(n^a) \cdot f^a\left[k^a, \ell^a\right] \tag{14}$$

The production function is separable in the sense that the choice of the optimal amount of land to use is independent of the other two inputs and their prices.

With the production function (14 we have a unit cost function:

$$c_a[r, w, q] = c_a[r, w] \cdot d(q) \tag{15}$$

When (15) replaces (9) in the GTFM, we have case which will be called the *Separable Three Factor Model* (STFM).

Theorem 1. *In the STFM factor-price equalization does not necessarily result. If there is any substitutability between labour and capital, Stolper-Samuelson magnification is a feature of the model, but its impact is moderate relative to the two-factor HOS model.*

Proof: Given relative product prices p, unit-cost price equality requires:

$$c_a[r, w] \cdot d(q) = 1 \tag{16}$$

$$c_m[r, w] = p \tag{17}$$

Given the standard factor intensity property for capital and labour, if two countries produce both products and share the same value of $d(q)$, factor-price equalization follows from (8) and (9). It is as if the price of manufactures in terms of the agricultural product were $p \cdot d(q)$in a completely standard HOS model. It is equally plain that if the two countries do not share the same value of $d(q)$, it is as if they faced different output prices, and factor-price equalization is not to be expected.

With Stolper-Samuelson magnification suppose a rise in p, and imagine that the changes which result do not include any alteration in the value of $d(q)$. Then the usual conclusions of the HOS model apply, and the real wage of labour in terms of either product will fall. However if there is any substitutability between the capital and labour inputs, the agricultural sector will shrink in size; the marginal product of land q will fall; and the agricultural sector will experience a fall of its

unit cost function in terms of r and w. The net effect is as if the rise in p were more moderate than its true arithmetic value. However magnification does not depend upon the size of the rise in p, so magnification will still result.

The proof of the theorem makes clear why separability is required, and also, looking just beyond the argument, how greater complications will be encountered is separability is not assumed. If one tries to push through a similar argument to the theorem, but using the cost-price-equality equations (9) and (10), rather than (9) and (15), what happens? So long as q is not altered, everything is as standard HOS reasoning. And when the agricultural sector shrinks, q will again fall. Without separability the change in q has a differential effect on the marginal attractiveness of the other two inputs. Then Stolper and Samuelson's "complicated patterns of complementarity and competitiveness" make themselves felt.

1.4. The Model without Separability

To choose a case which is easy to analyse, suppose that capital and land are perfect substitutes when employed in agriculture. Then so long as the demand for capital/land in agriculture is sufficiently high, the model will be essentially the familiar 2X2 HOS model. Some of the capital employed in agriculture will be seen on close inspection to consist of land, but that will not be important. There will be factor-price equalization, and magnification will be unmoderated.

Yet there can be differences. Assume that nearly all the "capital" employed in agriculture takes the form of land. Now p rises. In a standard HOS model a considerable volume of capital would migrate to the manufacturing sector. In the present case that cannot happen, because once all the true capital has left agriculture the remaining land is locked as a specific factor into agriculture. At this point our two-factor model splits into a three-factor model and the rent of land

and the rental of capital diverge. In fact the model is now Jones' model: capital and land are the two sector specific factors, and labour is the mobile factor.

A less special case is treated in the next theorem.

Theorem 2. *Given some substitutability between capital and labour in the model (9)-(13) above, if capital used in agriculture is a Hicksian complement of land, there will be Stolper-Samuelson magnification.*

Proof: Given relative product prices p, unit-cost price equality requires:

$$c_a[r, w, q] = 1 \tag{18}$$

$$c_m[r, w] = p \tag{19}$$

Suppose a small rise in p, and imagine that the changes which result do not include any alteration in the value of q. Then the usual conclusions of the HOS model apply, and the real wage of labour in terms of either product will fall. Again if there is any substitutability between the capital and labour inputs, the agricultural sector will shrink in size; the marginal product of land q will fall; and the agricultural sector will experience a fall of its unit cost function in terms of r and w. As with Theorem 1 above, the net effect is as if the rise in p were more moderate than its true arithmetic value. That moderates magnification but does not eliminate it. Now take into account the response of the relative use of labour and capital in the agricultural sector to a lower land rent. Because capital is the Hicksian complement of land, more capital will be retained in the agricultural sector, and more labour will migrate out of the sector, than would be the case with separability. Therefore the wage will fall even more in the manufacturing sector than would be the case with separability (where we have already shown magnification).

1.5. The Factor-Price Frontier in the New Toy Model

If capital and unskilled labour are the sole two inputs into either sector, the factor-price frontier must slope downwards, as these two prices must move in opposite directions to maintain cost-price equality. Therefore the only case that we need consider is when one of the two factors, unskilled labour and capital (let it be unskilled labour) is used in only one sector. Let the unit-cost-price equations be:

$$c_a\left[s, w\right] = 1 \tag{20}$$

$$c_m\left[r, s, w\right] = p \tag{21}$$

These equations define an implicit function between r and w. Differentiating (20) and (21) totally with respect to w gives:

$$\frac{\partial c_a\left[s, w\right]}{\partial s}\frac{ds}{dw} + \frac{\partial c_a\left[s, w\right]}{\partial w} = 0 \tag{22}$$

$$\frac{\partial c_m\left[r, s, w\right]}{\partial r}\frac{dr}{dw} + \frac{\partial c_m\left[r, s, w\right]}{\partial s}\frac{ds}{dw} + \frac{\partial c_m\left[r, s, w\right]}{\partial w} = 0 \tag{23}$$

From (22):

$$\frac{ds}{dw} = -\frac{a_l^a}{a_s^a} \tag{24}$$

Then, from (23):

$$\frac{dr}{dw} = \frac{a_s^m}{a_k^m} \cdot \frac{a_l^a}{a_s^a} - \frac{a_l^m}{a_k^m} = \frac{a_s^m}{a_k^m}\left[\frac{a_l^a}{a_s^a} - \frac{a_l^m}{a_s^m}\right] \tag{25}$$

The slope of the factor-price frontier is ambiguous, depending upon the relative intensity in the use of skilled and unskilled labour in respectively agriculture and manufacturing. This finding is more general, and richer, than the equivalent result

in the Jones (1971) model. In the plausible case - at least for the 1850s - in which manufacturing makes a more intense use of skilled labour, the factor-price frontier slopes upwards, as in Jones' original discussion.

1.6. The Abolition of the Corn-Laws

> "The urban working man suffered from the 'bread tax', and free trade was hailed as a remedy for all of common labor's social ills. Manufacturers suffered since they had to pay higher nominal wages, their export trade was repressed, and their profits were choked off." (Williamson, 1990, p.130)

Modern writings on economic history are full of economic theory. For that reason it is remarkable that economic historians have not spotted the relevance of Stolper and Samuelson's famous theorem for the assessment of the effects of the Corn Laws. An exception is Kindleberger (1975) who notes the connection within a much broader discussion but does not pursue it. Because the Corn Laws increased the demand for the unskilled labour used intensively in the production of food, thus producing a rise in wages, but also raised the price of grain, there is an apparent ambiguity as to what their effect was on the real wage of the industrial labourers who paid the Anti-Corn-Law League's "bread tax". The issues involved are broached in Bliss (1998).

Williamson (1990 p.131) asserts the existence of such an ambiguity without explaining why the Stolper-Samuelson result does not dispose of it. Williamson mentions capital market segmentation, and makes a distinction between *unskilled labour* and *common labour*. All this points to a more complicated model than a simple Stolper and Samuelson analysis uses, some of which difference may be accounted for by a greater specific factors component in Williamson's general equilibrium model. Even so, while economic historians may employ a great deal

of economic theory, they are surely not above sniping at economic theorists when the latter use over-simplified models. In that case, Williamson's failure to do that probably indicates that he did not have the Stolper-Samuelson model at the front of his mind.

	Agriculture	Manufacturing
Capital	20%	50%
Labour	40%	50%
Land	40%	-

Table 1.1: Factor Shares by Sector

The table shows factor shares for agriculture and manufacturing taken from Crafts (1985 p. 83 et seq.) The numbers shown are inconsistent with both the HOS model and with Jones' model. When land is ignored labour shares equally with capital in the output of manufacturing, while in agriculture labour takes twice what capital takes. In this sense manufacturing is capital intensive.

David Ricardo (1951) proposed a case which is in contradiction to the conclusions of the STFM:

> "It follows, then, that the interest of the landlord is always opposed to the interest of every other class in the community. His situation is never so prosperous, as when food is scarce and dear: whereas all other persons are greatly benefited by procuring food cheap."

Ricardo and the anti-corn-law agitators shared in common the view that the Corn-Laws benefited the landlord and harmed the capitalist. It is true that Cobden and Bright laid their emphasis on the interests of their labourers. Yet these factory owners did not argue energetically against their own particular interests

as capitalists, and their pamphlets claimed that the "bread tax" harmed manufacturers as much as it hurt labourers.

The STFM can embrace the Ricardo-Cobden-Bright conclusion. Obviously if labour and capital were perfect substitutes, they could lose equally from a rise in the price of food. But it might seem more reasonable to allow Stolper-Samuelson effect to place the interests of capital and labour in direct opposition to each other. And in that case labour would be the beneficiary of agricultural protection.

It would be absurd to impute to the Anti-Corn-Law League an understanding of Stolper-Samuelson 100 years before the paper was published. And in any case that result is a long-term result (the same is true of results which come out of the GTFM), and the propagandists of the Nineteenth Century may have had in mind something more like a specific -factors model.

1.7. Models of North-South Trade

Despite its simplicity, the HOS model has often been used in discussions of North-South trade or globalization. In simple discussions globalization has often been supposed to imply factor-price equalization; or at least a movement in that direction. Wood (1994) has promoted vigorously a model of North-South trade which reduces the analysis to an application of the 2X2 HOS model. He argues that capital is so perfectly mobile in the modern world that it can be neglected. That is equivalent to carrying out HOS analysis using unit cost functions dependent on three factor prices; but one, the cost of capital, is the same in all countries.

Wood's two immobile factors are skilled and unskilled labour. For these factors free(er) trade gives factor-price equalization, or a movement in that direction[1]. The consequence of opening up more North-South trade is a fall in the wage level

[1]Even with the same technology everywhere, there will not be factor-price equalization if trade is not completely free. Also richer countries may have higher productivity of all factors in equal proportion, when relative factor prices can be equalized without absolute equality.

of unskilled workers in the North and a rise in the wage of the same type of worker in the South. That would typically mean more inequality in the North, and less inequality in the South.

One problem with Wood's intruiging argument is that the evidence does not provide strong support for the view that that capital is perfectly mobile internationally. If we concede that point, a more realistic but still simple assumption is that capital is completely immobile. Then if we want to retain the distinction between skilled and unskilled labour, we would be forced to treat a model with three immobile factors. That can always be done, but it is complicated. Here we can apply a simpler model to the analysis. It is the STFM, but now capital and unskilled labour are the factors employed in both sectors; while skilled labour is employed in only one sector - called naturally the high-tech sector (or the H-sector for short). The other sector is the low-tech or L-sector. Relative to the L-sector, the H-sector is assumed to use capital more intensely than unskilled labour.

Even with free trade there will be no factor price equalization, not unless North and South happen to have just the right relative levels of skilled labour to bring about what here can only be a fluke result. Now suppose that the opening up of North-South trade causes the relative price of the L-sector good to fall in the North and to rise in the South. We have seen above that magnification features in the STFM. So because the L-sector uses unskilled labour more intensely than capital, the real return to capital will rise in the North (in terms of either product) and the real wage of unskilled labour will fall (in terms of either product). In the South mirror image movements of factor earnings (in the opposite direction) will be observed.

Because skilled labour is employed in the H-sector, it functions like land in the original discussion of the STFM, and in its application to the Corn Laws. For this reason:

- Magnification is moderated. So the fall in the real wage of unskilled labour in the North is less than it would be in the basic Stolper-Samuelson model with just two factors labour and capital.

- The wage of skilled labour will rise in the North and will fall in the South. Thus wages of skilled labour in the North will rise relative to wages of unskilled labour (more inequality); and in the South wages of skilled labour will fall relative to wages of unskilled labour (more equality). In terms of qualitative changes, all this is as in Wood's analysis.

It is difficult to compare changes quantitatively between the two models, our own and Wood's. In terms of the two kinds of labour they have different structures. However when we consider a version of Wood's model similar to our own in that skilled labour is used only in the H-sector, useful comparisons may be made.

Concentrate on the North. The relative price of the L-good falls. This raises the real return to capital. In the STFM capital is immobile. In Wood's model the change considered will cause a capital inflow, presumably from countries like the South, where the return to capital has fallen. In HOS theory a capital inflow into a small country has no effect on factor prices (the Rybcynski effect). In the STFM model such an inflow expands the H-sector, which further raises the real wage of skilled labour and depresses the real wage of unskilled workers in so far as these workers consume the H-good.

Already the results of the STFM are different from those which emerge from an HOS type of model. All the countries of the North together cannot be small. The price changes considered so far result simply from trade liberalization (say a cut in tariffs). These price changes induce output changes which will normally cause the terms of trade to move in the opposite direction from the price changes induced by freer trade. The more capital mobility there is, the stronger will be

the terms of trade buffering of trade liberalization. Therefore the STFM model predicts stronger relative wage changes than would the equivalent Wood model on account of capital immobility.

1.8. Conclusions

Our simple extension of the HOS trade model has provided a structure which lends itself to useful intuitive analysis, and to relevant applications. The presence of a third factor in one sector undermines the factor-price equalization result and also the simple Rybcynski property. However Stolper-Samuelson magnification does apply, although its power is moderated.

The model underlines what might be called the Corn Law puzzle. Why did agricultural protection not benefit the factory workers of industrial Britain? By retaining more workers in agriculture than would be the case with free trade, protection should, according to an HOS approach, have been harmful to industrial profits (as Ricardo stressed and may have motivated Cobden and Bright) but helpful to the the real wages of a mobile labour force in either sector. Probably writers at the time may have had in mind something more like a specific factors model than an HOS structure.

In another application the model may be used to enrich the treatment of North-South trade pioneered by Wood. Allowing capital to be immobile may make the model more realistic. However Wood's major conclusions concerning the effect of easier trade on wage inequality survive the etension to a three-factor framework.

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