Trade and Wages: What Can Factor Contents Tell Us?

by

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Abstract

Economists have long been using factor contents to test the factor proportions theory of comparative advantage. More recently, factor contents have been used to empirically identify whether trade is to blame for certain factor price changes. This paper explores the theoretical foundation for doing so, which has recently come under debate. It first delineates the information content of factor contents as such, and it then identifies thought experiments drawing on this information content that should prove useful for empirical research.

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1 INTRODUCTION

Drawing on the impeccable logic of comparative advantage, economists overwhelmingly support free trade. They typically do so by invoking a thought experiment in which, for given terms of trade or for a given set of potential trading partners, a country is shown under reasonable conditions to fare better under free trade than with restricted trade, say autarchy. Impeccable as it is, the story seems difficult to sell when it comes to public opinion and policy making. Why? Restrictive assumptions underlying the models used are no convincing explanation, for there are numerous examples where ideas relying on no less questionable assumptions have come to dominate policy making. A more obvious and convincing explanation is that aggregate gains from trade are typically coupled with distributional effects, as economists since the early days of comparative advantage have always been very careful to point out. If these are difficult to deal with, policy makers will, understandably, not be too excited about thought experiments highlighting aggregate gains from trade. But there is a somewhat subtler point relating to the above mentioned thought experiment. The usual story argues that, *in a given situation*, a country may gain from trade and should for its own sake reduce its trade barriers. It is, however, an entirely different question whether a certain *historical change* will be more harmful for a given country, or more difficult to deal with in terms of the distributional consequences, if it is open to trade than if it chose to run a more restrictive trade regime. History will hold different things for a country's residents, depending on whether it is part of a globalized economic environment, or whether it follows a policy of opening and closing its border at will. When indulging into this second kind of thought experiment, however, one should not lose track of the first. While a country may be adversely affected by some historical development because it is open to trade, the usual gains from trade argument still implies that, given this new situation, the country is likely to be better off under free trade than with trade restrictions. The implication then is that the gain lost through trade restrictions would have been even larger prior to this change. More importantly, individuals who are unfavorably affected by some historical change, given their country's openness to trade, need not be those who would gain from restricting trade in this new situation.

The second thought experiment, focusing on domestic consequences of outside forces, seems to be more in line with current concerns about globalization which importantly drive the resistance that economists face when trying to tell their tale of free trade. Very often in today's global goods and factor markets, far–away and sometimes arcane forces are perceived to impose unwelcome distributional changes on the domestic economy, and sometimes they even seem to make the whole country worse off. In addition to secular trends in specialization and migration, recent events have shown that even countries with sound macroeconomic policies are exposed to destabilizing forces initiated by unbalanced macroeconomic policies elsewhere in the world. Governments feel uneasy not only about these developments as such, but, more importantly, about what they can, or rather cannot, do about them. Fear of resurgent protectionist sentiment seems warrante; see Rodrik 1998. Most governments are presumably well aware that a retreat from globalization will not be without any cost, but they might hope to at least get back into the driver's seat. Historical experience provides little comfort. Recent research strongly suggests that the late 19th century period of mass migration and booming commodity trade was followed by intended policies of globalization backlash, mainly because of the unwelcome distributional effects that came with it (Williamson, 1998). While globalization today may have gone too far (Rodrik, 1997), a renewed backlash would most likely lead to worse. Hence, economists are called upon to shed light on hotly debated policy concerns about globalization, and in particular to separate true causation from cheap scapegoats, so as to foster a well balanced policy attitude.

Merely reiterating the principal case for free trade will not do much to convince the sceptics. There is a clear need to address specific scenarios in an empirical way, and to pay sufficient attention to distributional concerns in addition to overall gains when doing so. While recent events have temporarily shifted public concern from trade and migration to capital mobility, in the longer run trade is likely to remain an important issue. The success of the Uruguay round notwithstanding, there is important unfinished business, such as agriculture, services, and information technology, which the WTO intends to take up in a further round of negotiations. In addition, trade continues to be an important channel through which such important developments as systemic transformation in eastern Europe, or the emergence of new players elsewhere in the world, are felt in the more settled economies of western Europe or the US. In either case, fear of distributional consequences for wages will play an important role in the formation of the policies pursued. While such consequences have long been attended to in theory, empirical research on the relationship between trade and wages is relatively new. It developed in the last decade from the observed coincidence in many developed countries of a) an increase in earnings inequality, particularly between skilled and unskilled wage earners, and to some extent even a fall in real wage earnings for unskilled, and b) an increase in the level of trade with less developed countries due to multilateral or preferential trade liberalization, sometimes paralleled by a significant worsening of the aggregate trade balance. Meanwhile, a large body of literature has accumulated which tries to sort out to what extent this coincidence mirrors causation. Next to trade, the prime suspect identified was technological change. Indeed, a recent survey by Cline (1997) suggests that technology may play an equally important, if not dominant, role as an explanatory factor of wage movements.

However, a final verdict is still pending, and it is frustrated not only by details of interpretation, but also by methodological dissent. A large number of studies have in one way or another resorted to calculating the *factor content* of international trade in commodities, a concept which was originally developed to empirically test the Heckscher–Ohlin theory of comparative advantage; see Leamer (1984) and Helpman (1998). The principal idea underlying its use to identify possible sources of wage movements is that whenever (and for whatever reason) a country increases its net exports of skill intensive commodities relative to its net exports of raw labor intensive commodities, this should put upward pressure on relative wages for high skill labor. By calculating changes in high skill and low skill labor contents of *net* trade, perhaps augmented by migration flows, one might, therefore, hope to identify trade related sources of wage movements. Though trade theorists were never much enthused about this approach, it was widely used in the U.S. context (see, for instance, Borjas, Freeman and Katz, 1996, 1997, and Baldwin and Cain, 1997). In the European context, one might rely on this idea to estimate the effects of increased east–west trade on western and eastern European wages. Given its popularity in empirical research, and given the continuing relevance of the underlying policy issue, the theoretical foundation of the factor contents approach is worth investigating.

Recent papers by Krugman (1995), Panagariya (1998), Leamer (1999), and Deardorff (1999) have revealed important insights. While Leamer and Panagariya are very skeptical, Krugman and Deardorff are more sanguine about factor contents. The issue, then, does not seem to be settled yet. In this paper, I intend to provide a synthesis of the arguments as well as further insights. I argue that previous discussions have to some extent suffered from blurring two issues: a) The information content of factor contents as such, and b) how this information content may be exploited in specific thought experiments in a given empirical context. Section 2 first offers a few general remarks and then goes on to delineate the information content of factor contents in a reasonably general way, without any specific thought experiment in mind. In doing so, I draw on the seminal paper by Deardorff and Staiger (1988). In addition to trade, I shall explicitly discuss the role of changes in endowments and technology, and changes in the structure of complete specialization. General inequality restrictions will be addressed, as well as more restrictive cases assuming constant elasticities of substitution in different production sectors and in consumption. Section 3 then turns to specific thought experiments. The central contribution here will be a) to point out possible ways of designing specific thought experiments in which factor contents can tell us interesting things about the relationship between trade and factor prices, and b) to show how the different counterfactual equilibria emerging in these thought experiments must be interpreted. Moreover, section 3 also discusses issues of empirical calculation pertaining to such counterfactual equilibria. Section 4 offers some concluding remarks.

2 FACTOR CONTENTS: THEORY

Since factor contents of trade flows have played such a prominent role in *testing* Heckscher-Ohlin trade theory, it is worth emphasizing at the outset that the purpose here is not to derive testable Heckscher-Ohlin type propositions. Instead, in a very general way the theory is assumed to hold, and the issue is how it may be used to shed light on the relationship between trade and wages. In other words, the question is whether calculating factor contents is a useful way to *apply* the theory. One would expect that factor contents surely have some information content, but whether it is useful depends on what, precisely, we are interested in. The purpose of this section is to delineate the information content of factor contents.

2.1 Prices versus quantities

Given that the Heckscher–Ohlin model does indeed stress a strong relationship between trade liberalization (or protection) and real wages, hallmarked by the celebrated Stolper–Samuelson theorem, it is not surprising that researchers should turn to it in their search for trade related sources of wage developments. What is surprising, however, is that they should do so by focusing on factor contents. After all, the factor content of trade relates to *quantities*, while the concern addressed relates to factor *prices*. One of the central tenets of the Heckscher-Ohlin theory is that in an open economy domestic factor prices are to a large extent driven by world commodity prices (perhaps distorted by trade policies), without any clear-cut implication regarding the quantities traded. Trade theorists have, therefore, repeatedly pointed out that looking at trade flows and factor contents is prone to misleading conclusions, or at least doesn't shed much light on the issue at hand. The relevant variables to look at, they argue, are changes in relative goods prices and sectoral factor productivity; see for instance Richardson (1995).

Should we, then, take a different route, trying to explain wage movements by changes in prices on world commodity markets? There are reasons to think twice. First, it is potentially misleading to emphasize that factor prices are 'driven' by commodity prices, as it seems to suggest that goods prices may be seen as exogenous. This is only true for a small country, which is a questionable presumption, at least when discussing the role of trade for wage decline in the industrialized world; see Krugman (1995). In a similar vein, it should be noticed that the Stolper–Samuelson theorem is not really a *causal* relationship, but a *general equilibrium relationship between two sets of endogenous variables* (goods prices and factor prices). Hence, from an empirical point of view the relevant question is what are the exogenous forces that jointly drive goods and factor prices in a certain way, and in some given historical period.

One may envisage research programs pursuing this line with varying degrees of purism, including in particular the estimation of reduced form factor price equations as well as simulation experiments based on general equilibrium models. As a second point, however, one may emphasize pragmatism. More specifically, weighing the cost of research against the value of the results achieved, it is hard to ignore the simple fact that factor contents is a concept that is relatively easy to implement empirically, partly because they are more readily observed than prices. It is therefore important to fully explore its information content with respect to the general aim of understanding wage movements. This is reinforced by the fact that, before the issue had even arisen, Deardorff and Staiger (1988) have shown that it is indeed possible to rigorously derive factor price interpretations of factor contents. It would thus be wrong to outrightly view factor contents as an empirical tool with a loose end and no clear relationship to theory.

2.2 Domestic versus outside changes

In the literature on trade and wages, a key question asked is to what extent observed wage (or, more generally, factor price) movements can be *attributed* to trade changes. Given that factor prices and trade must always be seen as *jointly determined* by exogenous changes, this seems like an odd question to ask. Specifically, examining a statistical relationship between trade and wages, and attributing any residual wage movement which remains unexplained by trade to other factors (technology, say), is fundamentally flawed. A completely different question, more in line with the introduction above, is to what extent the exogenous changes driving wages represent *external*, or outside forces, as opposed to sources that lie within the *domestic* economy. However, while it is always true that trade (in addition to factor movements) is the vehicle through which outside forces affect the domestic economy, there is little reason to believe that factor contents provide a reliable key to the relative importance of such external, as opposed to internal changes. Indeed, exogenous domestic changes (endowments, technology, preferences) may cause much co–movement in wages and trade, even absent any external change, just as external changes may exert a large influence on wages without affecting trade a lot. Examples for both are given in Leamer (1999), hence we need not go into any detail.[1] In general, therefore, factor content calculations seem ill suited a priori to separate domestic from external causes of wage changes. However, dismissing factor contents on this account is premature. As I shall argue below it boils down to the design and careful interpretation of useful thought experiments.

Now, one is tempted to argue that at least if in a specific period there is no domestic change whatsoever, then factor contents are a valid indicator of outside forces on domestic factor prices. In a sense this is certainly true, but it provokes two additional remarks. First, it is still possible that large wage movements are accompanied by minimal trade (and factor content) changes, the reason simply being that factor prices are closely related to commodity prices, but not nearly so to the quantities traded. And secondly, what can be gained from calculating factor contents if wage changes have been observed to start with? However large or small, they must in this case be attributed *in full* to external forces. It would, therefore, seem pretty meaningless to calculate factor contents if factor price changes have been observed to start with. Only if for some reason factor price changes are not directly observable might one want to turn to factor contents for a useful inference.

This apparently leaves us with a rather limited scope for useful application of factor contents, limited to cases where there are only external forces at work and where for some reason we are unable to observe factor price changes directly. But things start looking different, once we are willing to consider *hypothetical* changes, or thought experiments, instead of *historical* changes proper. Deardorff and Hakura (1994) have been the first to suggest that this might be a promising way to frame questions about the relationship between trade and wages that are both precise and interesting. They call them "but for" questions, since in one way or another they amount to thought experiments where a given historical situation is compared with a hypothetical situation which in all respects is the same, except for some well defined difference in trade flows. Krugman (1995) follows this idea in his line of defense against fundamentalist critics of factor contents, as does Deardorff (1999) in his response to Leamer (1999). I shall

[1] Further examples may be found in Bhagwati and Dehejia (1994), Deardorff and Hakura (1994), and Richardson (1995).

return to this issue when considering possible thought experiments below.

2.3 Trade and corresponding autarchy

Trading equilibrium: I assume that the domestic economy is exogenously endowed with a certain number of primary factors. Using a convex, *constant returns to scale* technology with *no joint–production*, it produces final commodities which may be greater or smaller in number than primary factors.[2] For easier distinction from scalar magnitudes, I shall use boldfaced symbols to indicate vectors and matrices. A prime will indicate matrix or vector transposition. The notation, then, is as follows:

- $\mathbf{V}$ vector of domestic endowments with primary factors
- $\mathbf{Q}$ vector of commodities produced domestically
- $\mathbf{C}$ vector of commodities absorbed domestically
- $\mathbf{p}$ vector of domestic commodity prices corresponding to $\mathbf{C}$
- $\mathbf{w}$ vector of factor prices corresponding to $\mathbf{V}$
- $\mathbf{A}$ matrix of cost-minimizing inputs per unit of output, given $\mathbf{w}$

For any given trading equilibrium, commodities absorbed domestically may thus be grouped into two subsets $\mathcal{Q}$ and $\mathcal{N}$, respectively, with $\mathcal{Q}$ indicating those commodities produced at home and $\mathcal{N}$ indicating non–competitive imports.[3] We thus have $\mathbf{C}' = \left[\mathbf{C}^{\mathcal{Q}}\,\mathbf{C}^{\mathcal{N}}\right]$, $\mathbf{p}' = \left[\mathbf{p}^{\mathcal{Q}}\,\mathbf{p}^{\mathcal{N}}\right]$, and $\mathbf{A}' = \left[\mathbf{A}^{\mathcal{Q}\prime}\,\mathbf{A}^{\mathcal{N}\prime}\right]$. We define a diagonal matrix $\mathbf{Z}$ of dimension equal to the number of non–competitive imports where the i–th diagonal element, $z_i > 1$, is the ratio between minimum unit costs of producing good i, given factor prices $\mathbf{w}$, and the corresponding

[2] Trade theorists often identify their models as either being of the mobile factors (or Heckscher–Ohlin) or of the specific factors (or Ricardo–Viner) type. The former is typically associated with the long run and has the number of commodities at least equal to the number of factors, while the latter, almost by necessity, has more factors than goods and is usually associated with the short run. Either interpretation is possible for the model used here. However, empirical applications of factor contents typically restrict the number of factors in such a way that the relevant interpretation is of the Heckscher–Ohlin type. This interpretation is also favored by the emphasis placed on non–competitive imports; see below.

[3] Although widely used, the term non–competing imports is a bit misleading here. These imports are very much competitive, so much so that domestic production of such goods has ceased, due to costs exceeding prices.

price p_i. Moreover, we define $\mathbf{T}$ as the net trade vector, i.e., the difference between domestic production and absorption. Any competitive equilibrium of this trading economy is fully described by a set of full employment conditions and a set of zero profit conditions:

$$\mathbf{A}^{\mathcal{Q}}\mathbf{w} = \mathbf{p}^{\mathcal{Q}} \tag{1a}$$

$$\mathbf{A}^{\mathcal{N}}\mathbf{w} = \mathbf{Z}\mathbf{p}^{\mathcal{N}},\ \mathbf{Z} \gg \mathbf{0} \tag{1b}$$

$$\mathbf{T} = \begin{bmatrix} \mathbf{Q} - \mathbf{C}^{\mathcal{Q}} \\ -\mathbf{C}^{\mathcal{N}} \end{bmatrix} \tag{1c}$$

$$\mathbf{A}^{\mathcal{Q}\prime}\mathbf{Q} = \mathbf{V} \tag{1d}$$

Equations 1a through 1c are the familiar zero profit conditions, while equation 1d states full employment. The zero profit conditions appear in a somewhat unconventional form in two respects. First, we use variables z_i to measure how much domestic cost exceeds prices for non–competing imports. And secondly, the complementary slackness condition for non-competitive imports appears in a somewhat unconventional form which states that for these goods net exports are equal to $-\mathbf{C}^{\mathcal{N}}$. This implies, as required, that there is no domestic production for these goods.[4]

Notice what we have *not* assumed for this equilibrium. We did not assume that trade be free or balanced, nor did we require international factor price equalization or a common technology for this country and its trading partner(s). For instance, if we denote the vector of (specific) trade taxes by $\mathbf{t}$, then aggregate income may be written as[5]

$$Y = \mathbf{p}^{\mathcal{Q}\prime}\mathbf{Q} + \mathbf{t}'\mathbf{T}, \tag{2}$$

where $\mathbf{p}^{\mathcal{Q}\prime}\mathbf{Q}$ is income at domestic prices, and $\mathbf{t}'\mathbf{T}$ is net revenue from trade policy. The trade balance at world prices is

$$b = \left(\mathbf{p}^{\mathcal{Q}} - \mathbf{t}^{\mathcal{Q}}\right)'\mathbf{Q} - \left(\mathbf{p} - \mathbf{t}\right)'\mathbf{C}, \tag{3}$$

[4] Regarding the Heckscher–Ohlin versus Ricardo–Viner interpretation of the model, one should note that linearly homogeneous production functions with positive amounts of all specific factors implies that there will be positive production of all goods. Hence, emphasizing non–competitive imports makes sense only in a Heckscher–Ohlin interpretation.

[5] More specifically, $t_i > 0$ indicates a tariff if $T_i < 0$, while it indicates an export subsidy if $T_i > 0$.

where $\mathbf{p}' = \left[\mathbf{p}^{\mathcal{Q}\prime}\, \mathbf{p}^{\mathcal{N}\prime}\right]$ and $\mathbf{t}' = \left[\mathbf{t}^{\mathcal{Q}\prime}\, \mathbf{t}^{\mathcal{N}\prime}\right]$, and world prices are $\mathbf{p}^* = \mathbf{p} - \mathbf{t}$. We may interpret $\mathbf{t}$ as including tariff–equivalents of quantitative restrictions, with $\mathbf{t}'\mathbf{T}$ including rents arising from such restrictions. Factor income is

$$\bar{Y} = \mathbf{w}'\mathbf{A}^{\mathcal{Q}\prime}\mathbf{Q} = \mathbf{p}^{\mathcal{Q}\prime}\mathbf{Q} = \mathbf{w}'\mathbf{V}, \tag{4}$$

and expenditure is

$$E = Y - b = \mathbf{p}'\mathbf{C}. \tag{5}$$

Corresponding autarchy equilibrium: Following Deardorff and Staiger (1988), we may now construct an autarchy equilibrium that corresponds to the above trading equilibrium. This is a hypothetical equilibrium where a country would reach the same equilibrium prices for goods and factors – without any trade – as it does in the trading equilibrium. If such *corresponding autarchy equilibria* exist for two different trading equilibria, we may use them to treat the factor price changes between the trading equilibria as if they had happened in a closed economy. The factor contents of trade provide the key link between the trading equilibria and their autarchy counterparts. Hence, whatever we know about factor price changes in a closed economy should help us to see if and how factor contents carry useful information on factor prices obtaining in different trading equilibria.

Trade in the above equilibrium has two effects. First, for commodities $\mathcal{Q}$, it allows the economy to consume quantities that differ from domestic production, without there being any difference, at the margin, in the opportunity cost between producing them at home and obtaining them through imports. And secondly, for commodities $\mathcal{N}$, trade affords the economy goods at a cost which is lower than the opportunity cost of producing them at home. We may identify this latter effect of trade as equivalent to some technological progress, and without loss of generality we may measure it by means of an *equivalent Hicks–neutral progress* (see also Deardorff, 1999). Indeed, this is exactly what the matrix $\mathbf{Z}$ above does. More specifically, if the economy were to experience a Hicks–neutral technical progress such that instead of using (cost–minimizing) inputs $\mathbf{A}^{\mathcal{N}}$ per unit of output it would use inputs $\widetilde{\mathbf{A}}^{\mathcal{N}} = \mathbf{Z}^{-1}\mathbf{A}^{\mathcal{N}}$, then it would find in the above equilibrium that the opportunity cost of obtaining goods $\mathcal{N}$

through imports is equal, at the margin, to producing them at home. I shall therefore refer to $\mathbf{Z}$ as the Hicks-matrix.

We now define the factor content of the trading equilibrium as

$$\widetilde{\mathbf{F}} = \left[\mathbf{A}^{\mathcal{Q}\prime}\, \tilde{\mathbf{A}}^{\mathcal{N}\prime}\right] \mathbf{T}. \tag{6}$$

Notice that this is a hypothetical construct. We treat non–competitive imports as if they were produced at home, taking advantage of the above mentioned trade–equivalent technical progress.[6] Notice also that we may write

$$\mathbf{V} = \widetilde{\mathbf{F}} + \widetilde{\mathbf{F}}^{C}, \tag{7}$$

where $\widetilde{\mathbf{F}}^{C}$ is the hypothetical factor content of domestic absorption, employing again the domestic input mix according the improved technology.

Envisage an economy which has endowments

$$\widetilde{\mathbf{V}} = \mathbf{V} - \widetilde{\mathbf{F}} \tag{8}$$

plus technology $[\mathbf{A}^{\mathcal{Q}\prime}\, \widetilde{\mathbf{A}}^{\mathcal{N}\prime}]$, but which otherwise is the same as the economy underlying the above trading equilibrium. It can now be shown that the equilibrium for this economy is a *corresponding autarchy equilibrium*. It has the same prices for goods and factors, with production equal to $\mathbf{C}$ and, therefore, $\mathbf{T} = \mathbf{0}$. The proof is perfectly analogous to the one without non–competing imports which is provided by Deardorff and Staiger (1988), hence we may proceed without. It must be noted that this holds for an arbitrary trade policy which, of course, is an important determinant of trade and thus its factor content. This begs a seemingly awkward questions, since we may conceive of different trade policies leading to the same trade vector, but with different factor prices. How can an economy with endowment $\widetilde{\mathbf{V}}$ calculated as in 8 with a given trade vector behind $\widetilde{\mathbf{F}}$ have different autarchy factor prices? The answer is that such differences in factor prices would be reflected in, and thus captured by, different factor input coefficients used to calculate the factor content. Hence, whatever the trade policy behind a given trade vector, and whatever the associated factor prices, an economy with endowment $\widetilde{\mathbf{V}}$ and technology $\widetilde{\mathbf{A}}$, if left in isolation,

[6] Note, specifically, that the factor content of trade as defined in 6 is different from the *actual* factor content used in Helpman (1984) for situations without factor price equalization, where foreign input coefficients are used to calculate the factor content of imports.

would reproduce these prices as an autarchy equilibrium. This point will be important to bear in mind when considering various thought experiments in section 3 below. It should further be noticed that the aggregate value of net exports of factor content is equal to the aggregate trade balance at domestic prices:

$$\mathbf{w}'\widetilde{\mathbf{F}} = \mathbf{w}'\mathbf{A}^{\mathcal{Q}\prime}\mathbf{Q} - \mathbf{w}'\left(\mathbf{A}^{\mathcal{Q}\prime}\mathbf{C}^{\mathcal{Q}} + \widetilde{\mathbf{A}}^{\mathcal{N}\prime}\mathbf{C}^{\mathcal{N}}\right) = b + \mathbf{t}'\mathbf{T} = \mathbf{w}'\mathbf{V} - E. \qquad (9)$$

While trade is trivially balanced in the autarchy equilibrium, it fully corresponds to a trading equilibrium which may exhibit unbalanced trade. In other words, expenditure $\mathbf{p}'\mathbf{C}$ in the autarchy equilibrium is always equal to $\mathbf{w}'\widetilde{\mathbf{V}}$, but it need not be equal to $\mathbf{w}'\mathbf{V}$.

Figure 1: Factor contents and non–competing imports

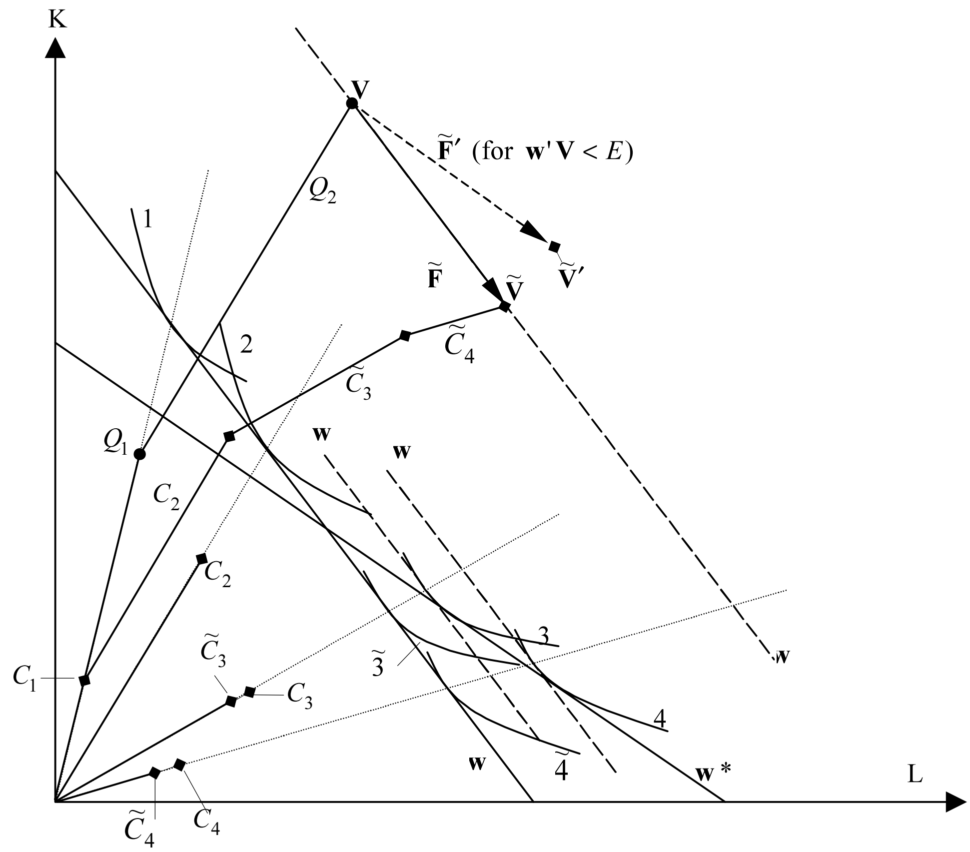

Figure 1 illustrates the argument for four goods, where goods 3 and 4 are non–competing, with unit–value isoquants 3 and 4. With factor prices $\mathbf{w}$, these goods will not be produced at home, but only abroad where factor prices are $\mathbf{w}^*$. C_3 and C_4 are the factor bundles that would be used if the home country were to produce its own consumption of these goods, respectively. The equivalent Hicks–neutral technology improvement represented by the matrix $\mathbf{Z}$ above would move the unit value isoquants for these goods to $\tilde{3}$ and $\tilde{4}$, respectively. Producing its own consumption of these goods with this improved technology, the home economy would use factor bundles $\tilde{C}_3$ and $\tilde{C}_4$. As drawn, with the other consumption bundles C_1 and C_2 as well as production bundles Q_1 and Q_2, the home economy has balanced trade, $\mathbf{w}'\widetilde{\mathbf{F}}= \mathbf{0}$. If expenditure were larger than factor income, a factor content vector like $\widetilde{\mathbf{F}}'$ would materialize which has a negative value at factor prices $\mathbf{w}$.

2.4 The information content of factor contents

Some of the discussion in the literature on factor contents has suffered from blurring two conceptually distinct issues. One relates to the information content of factor contents with respect to factor prices. The issue is to find out under what conditions, and in which sense, factor contents can tell us interesting things about factor prices in two trading equilibria. And the other is to design an interesting thought experiment which allows to exploit this information content of factor contents in an empirical context. Given two trading equilibria indexed by subscripts 1 and 2, the first issue is whether knowledge of $\widetilde{\mathbf{F}}_1$ and $\widetilde{\mathbf{F}}_2$ can tell us anything about $\mathbf{w}_2$ as compared to $\mathbf{w}_1$. The second issue is how these two equilibria should be defined in an empirical exercise, such that factor contents can tell us interesting things.

It might be argued that if both equilibria are fully observed (including exogenous variables), we wouldn't be bothering about the information content of factor contents. However, the next section will show that it is precisely situations like this that afford factor contents a very useful role in carrying out interesting thought experiments. On the other hand, if for the purpose at hand we can rely on a computable general equilibrium model, there is surely no use in resorting to factor contents. For instance, if we picture the two equilibria as being related to each other by a well defined change in a fairly limited set of exogenous variables (trade barriers, say), and if we can calibrate a suitable CGE model to equilibrium 1, then we can analyze equilibrium 2 (including $\mathbf{w}_2$) in an ex ante sense as a counterfactual solution for this model. Suppose, however, that a fully specified CGE model is not available for the kind of exogenous change that one is concerned about. The changes may be large in number, too complicated to model, or we may not even have a precise notion of what, precisely, they are. This pretty much seems to fit the situation addressed in the recent literature on trade and wages. In addition, CGE analysis is much more demanding on both model structure and data than calculating factor contents, and the use of a particular tool of analysis should ultimately be driven by its return compared to the effort required. With this in mind, what is the information content of factor contents?

Given the existence of corresponding autarchy equilibria for both 1 and 2, does combining empirical knowledge of factor contents with theoretical knowledge of how factor prices are determined in closed economies give useful insights on $\mathbf{w}_2 - \mathbf{w}_1$? Drawing on 8, in general we have

$$\widetilde{\mathbf{V}}_2 - \widetilde{\mathbf{V}}_1 = \mathbf{V}_2 - \mathbf{V}_1 - \left(\widetilde{\mathbf{F}}_2 - \widetilde{\mathbf{F}}_1\right). \tag{10}$$

A key question therefore is how $\widetilde{\mathbf{V}}_2 - \widetilde{\mathbf{V}}_1$ relates to $\mathbf{w}_2 - \mathbf{w}_1$. Dixit and Norman (1980) have shown that there is an inequality restriction on autarchy factor price differences and corresponding endowment differences between two countries sharing common preferences and a common technology. If we apply this to a comparison across two autarchy equilibria for a given economy with a constant technology we obtain

$$(\mathbf{w}_2 - \mathbf{w}_1)' \left(\widetilde{\mathbf{V}}_2 - \widetilde{\mathbf{V}}_1\right) \leq 0. \tag{11}$$

Notice that a constant technology implies $\mathbf{Z}_2 = \mathbf{Z}_1$; see below. Notice also that for this result to hold, aggregate expenditure must be the same in both equilibria. This has two interpretations. One is to assume that expenditure remains constant across equilibria for some given initial price normalization (the choice of some numéraire commodity, say). This implies that, unless aggregate income $\mathbf{w}'\mathbf{V}$ remains constant as well, there will be a change in the trade balance. In other words, for any *given* price normalization inequality 11 does not generally hold. A preferable alternative is to assume that prices are separately normalized in the two equilibria, such that aggregate expenditure is unity in both. In general, this implies a change in the price normalization across equilibria. As pointed out by Deardorff and Staiger (1988), in this case factor prices may directly be interpreted as distributional variables, indicating factor incomes as shares of aggregate expenditure.[7] Notice, however, that with this interpretation factor price changes loose any significance whatsoever with respect to welfare changes as between situations 1 and 2.

A further observation is that in an open economy factor price changes relate to changes in the factor content of consumption in the same way as they relate to changes in endowment in a closed economy. This follows from 11 if 7 is inserted into 10. But what about the factor content of trade? From 10 and 11 it is evident that, in general, the factor content of trade as such has no information content with respect to factor prices. The weak Deardorff and Staiger (1988) result, which is an inequality restriction analogous to 11, but relating to the factor content, follows only if a) $\mathbf{V}_2 - \mathbf{V}_1 = 0$, and b) if situations 1 and 2 are such that the two hypothetical autarchy technologies and preferences are the same. How restrictive these conditions are very much depends on the specific thought experiment considered; see below. Several problems may become relevant. A first point is that the policy environment must not change across equilibria. This is worth pointing out, as it is hardly ever mentioned, but I shall not dwell on it any further. Further problems arise if there are simultaneous changes in endowments, or if there are changes in technology and/or preferences. Technological change may, in turn, occur in two distinct ways. There may be equivalent Hicks–neutral technological progress capturing the role of non–competing imports, or there may be genuine technological progress of whatever kind across equilibria. I shall take up these problems in turn.

Endowment changes: If technology is constant across equilibria but endowment changes cannot be ruled out, one is tempted to explore into possible relationships between changes $\widetilde{\mathbf{F}}_2 - \widetilde{\mathbf{F}}_1$ and $\mathbf{V}_2 - \mathbf{V}_1$ across time, given the established

[7] Helpman (1984) shows, comparing two countries 1 and 2, that without normalizing expenditure in the above way, we have $(\mathbf{w}_2 - \mathbf{w}_1)' \left(\lambda_2 \widetilde{\mathbf{V}}_2 - \lambda_1 \widetilde{\mathbf{V}}_1\right) \leq 0$, with λ_1 and λ_2 two arbitrary positive constants. Setting these equal to 1 has the above intuitive interpretation.

Heckscher–Ohlin–Vanek tradition of relating factor contents to endowment differences at any given point in time. But this does not lead us very far inasmuch as these relationships assume international factor price equalization, which much of the literature in this tradition does. A notable exception is Helpman (1984) who explores the relationship between *bilateral* factor contents and factor price differences between countries with differing endowments. Such a relationship seems to offer a more direct route to investigate the information content of factor contents with respect to factor price changes for a given country across time. Unlike the Deardorff–Staiger approach, any interpretation of factor contents so obtained would hold with simultaneous endowment changes. To my knowledge, this approach has not been explored in the literature on trade and wages. I do so in appendix A.1, but the result is disappointing. While it is possible to find relevant restrictions on factor contents and factor prices, these are of a form which negates empirical implementation. One is thus left with cases where $\mathbf{V}_2 = \mathbf{V}_1$, and where the information content of factor contents derives from the weak DS result. Leamer (1999) and others argue that this is a fatal limitation. This is certainly true if one looks at *historical situations* across time. However, the restriction may be innocuous for carefully designed *thought experiments*. I shall return to this in the next subsection, after considering technology changes.

Non–competing imports: In the presence of non–competing imports, each corresponding autarchy equilibrium features a hypothetical technology, determined by the respective Hicks–matrix $\mathbf{Z}$ which relates to the underlying true technology through the prevailing equilibrium prices; see equation 1b above. For the time being, we assume a constant true technology. If $\mathbf{Z}_2 = \mathbf{Z}_1$, we may look at the two autarchy equilibria as having the same technology and the presence of non–competing imports is irrelevant; see also Deardorff (1999). In general, however, the two Hicks–matrices will differ, and for purposes of interpretation the endowment change $\widetilde{\mathbf{V}}_2 - \widetilde{\mathbf{V}}_1$ must be seen as paralleled by an equivalent Hicks–neutral technology change for some goods. We thus have a composite scenario: Absent any technological change, endowment changes are related to factor price changes according to 11. On top of this, what is the additional effect arising from a Hicks–neutral technological change $\mathbf{Z}_2 - \mathbf{Z}_1$?

Trade economists have often pointed out that in an open economy the effect of technological change on factor rewards depends on the factor intensity of the sector where it occurs, rather than its factor bias.[8] In this way, even Hicks–neutral change may have important consequences for factor prices. However, in the present case we are talking about an economy which, by construction of the argument, is closed to trade. And this makes a huge difference. Suppose a closed economy moves from an endowment point $\widetilde{\mathbf{V}}_1$ to $\widetilde{\mathbf{V}}_2$ with a constant technology. There will be an initial allocation of resources reached in situation 2. Now renumber the isoquants according to the Hicks–neutral technological change; see figure 1. Whatever the number and directions of changes, the initial allocation remains efficient. But it has different outputs, and the question is whether it can be a full autarchy equilibrium. If it is, then *relative* factor prices will not be affected by the technology change.[9]

With the initial allocation, output of commodity i changes by $\tau_i \times 100$ percent, where $\tau_i = z_{i,2} - z_{i,1}$. Notice that τ_i, unlike $z_{i,2}$ or $z_{i,1}$, may well be negative, for instance if good i is a non–competitive in situation 1, while it is competitively produced at home in situation 2. If $\hat{p}_i$ is the relative price change for good i, the output value of the initial allocation in sector i changes by $(\tau_i + \hat{p}_i) \times 100$ percent. The zero profit conditions require that the costs of all allocations change in line with their output value. If relative factor prices are to remain constant, all factor prices must change by a common factor which must in turn be equal across sectors. Indeed, keeping in mind that we have chosen a normalization such that expenditure is always equal to unity, this factor must now be set to zero, ruling out any change in aggregate expenditure due to the technology change considered. Hence, we have $\hat{p}_i = - \tau_i$. Under Cobb–Douglas preferences and constant expenditure, this implies $\widehat{C}_i = \tau_i$ in which case the initial allocation is indeed a full equilibrium.[10] More generally, if σ_{ij} is the elasticity of substitution in demand, we have $\widehat{C}_i - \widehat{C}_j = \sigma_{ij} (\hat{p}_j - \hat{p}_i)$. For instance, if $\sigma_{ij} > 1$ we have $\widehat{C}_i - \widehat{C}_j > \tau_i - \tau_j$, i.e., excess demand for good

[8] See, for instance, Richardson (1995) and Jones, and Engerman (1996).

[9] Note that we have already restricted our attention to relative factor rewards through our choice of normalization above.

[10] Notice that there are no further requirements, whatsoever, on production. Krugman (1995) treats technological change in a two commodity model using fixed input coefficients, whereas Deardorff (1997) assumes Cobb–Douglas technologies.

i is larger than for good j. In a two two–by–two world, this would imply that the technology change has the additional effect of increasing the price of good i relative to good j, thereby changing income distribution in favor of good i's intensive factor. Notice that this holds irrespective of whether $\tau_i > \tau_j$, or the other way round! Whatever is the case, this same technological change would work against the factor used intensively in good i if $\sigma_{ij} < 1$.

Thus, the consequence of non–competing imports for factor price changes is relatively easy to pin down for the two–by–two case, or else if individual commodities are affected in isolation; see also Krugman (1995), and Deardorff, (1999). A conclusion holding more generally is that it is immaterial whether the sectors with an equivalent technological improvement (non–competing imports in situation 2 but not in situation 1) or deterioration (non–competing imports in situation 1 but not in situation 2) are intensive in some factor (skilled labor, say). It is the elasticities of substitution in demand that matter instead. We may venture to say, albeit somewhat loosely, that relative to a situation where non–competitive imports do not matter, we will see those factors favorably affected which are intensively used in the commodities favored by a high elasticity of substitution in demand.

Technological change proper: Technology, next to trade, has been the prime suspect for contributing to the erosion of unskilled wage income relative to other incomes. Indeed, much of the literature has concluded that technological change, rather than changes in trade flows, is the main culprit. Generally, we must expect that the information content of factor contents almost completely vanishes if we allow for arbitrary technological changes. In a sense, this is a trivial observation which, one might argue, is of little help. At the same time, however, it is less innocuous than it may seem, for it negates the procedure commonly used in empirical research to separate technology from trade effects. This procedure requires that one first tries to find out how much of an observed factor price change can be attributed to trade, and then to attribute the rest to some *unspecified* technological change; see Cline (1997). This is fundamentally flawed. With an unspecified technological change operating in the background, factor contents have no information content whatsoever and, therefore, also do not permit such a residual interpretation. This is a general point, extending beyond factor contents, which has not been sufficiently noticed in empirical research. Once we allow that technology may be changing, we can no longer measure the effects of trade separately, whether through factor contents or in some other way, since these effects will depend on the exact nature of the technology change.

Thinking about *specific forms* of technological change, what is the appropriate perspective? As mentioned above, trade economists have often looked at technological change from the point of view of an open economy where the sector bias plays an important role. In the extreme case where commodity prices of traded goods are fixed (small economy), it is immediately clear that any non–proportional Hicks–neutral technological improvement in different sectors could never be accommodated without relative factor price changes. In such an economy, unlike a closed one, technological progress of this kind enforces factor price changes in a way which exactly mirrors the effect of a change in relative goods prices; see, for instance, Richardson (1995), and Jones and Engerman (1996). Conversely, any factor–augmenting technological improvement will be devoid of factor price effects unless the economy is pushed outside its present diversification cone.

All of this is fairly well known, but is this the right perspective? Krugman (1995) argues that the small open economy assumption is misleading in the present context, at least if we are investigating causal factors for wage movements that have hit the whole industrial world. But, somewhat paradoxically, even if we do look at a small economy we should rely on the closed economy assumption when exploring the implications of technological change. The reason is that we focus on hypothetical autarchy equilibria when interpreting factor contents. Whatever the technologies available in situations 1 and 2, respectively, $\widetilde{\mathbf{V}}_1$ and $\widetilde{\mathbf{V}}_2$ as defined in 8 are endowments of the corresponding autarchy equilibria. I.e., with these endowments our economy would end up producing what it consumes in the respective trading equilibrium, with the respective technology and commodity as well as factor prices. Whatever the precise nature of the technological change in an open economy between 1 and 2, the attendant factor price changes are the same as in a closed economy with a simultaneous endowment change $\widetilde{\mathbf{V}}_2 - \widetilde{\mathbf{V}}_1$. In other words, once we take into account the trade effect of a technological change via $\widetilde{\mathbf{F}}_2 - \widetilde{\mathbf{F}}_1$, any *remaining* effect on factor prices then follows the logic of a closed economy. But this still leaves us in a very uneasy position unless we know something about the technological change to reckon with. As with endowment changes, we are left with an unambiguous information content of factor contents only if we can construct our two equilibria in such a way that we may assume with a safe margin of error that technologies 1 and 2 are the same. Again, this is a question of choosing the right thought experiment to which I shall return in a minute.

Strong results: So far we have only considered what has meanwhile become known as a weak result: an inequality restriction on factor contents and factor price changes. In their seminal paper, Deardorff and Staiger (1988) have shown a strong result for a log–linear economy where preferences as well as technologies are Cobb–Douglas throughout. In this case the share of domestic expenditure on each commodity is constant, as is the cost share of each factor in each commodity. If expenditure on each good is equals to its output value, as by necessity in an autarchy equilibrium, it follows that aggregate income for each factor is a constant fraction of overall expenditure: $w_k \tilde{V}_k = \beta_k E$. Remembering that we have normalized prices such that $E = 1$ in both equilibria, we have $w_{k,2} / w_{k,1} = \tilde{V}_{k,1} \big/ \tilde{V}_{k,2}$, or equivalently

$$\frac{w_{k,2} - w_{k,1}}{w_{k,1}} = \frac{\tilde{F}_2 - \tilde{F}_1}{\tilde{V}_{k,2}}. \tag{12}$$

This equation simply states that for a log–linear economy with constant expenditure the general equilibrium own price elasticity of aggregate factor demand is unity, and the cross price elasticities are zero. In empirical applications it is often assumed that this may be generalized to a non–unitary own price elasticity, drawn from outside econometric research, maintaining zero cross price elasticities; see for instance Borjas, Freeman and Katz (1996, 1997). Deardorff (1999) has shown that such a case indeed arises if the economy is CES, with a common elasticity of substitution in preferences and all production functions. We then have

$$\widehat{\mathbf{w}} = -\frac{1}{\sigma}\mathbf{I}\,\widehat{\mathbf{V}}, \tag{13}$$

where σ is the common elasticity of substitution. Appendix A.2 shows that this follows as a special case from a more general relationship between factor demands and factor prices in a closed economy where elasticities of substitution are allowed to differ. Panagariya (1998) shows that in a CES economy with identical elasticities, relative factor prices are driven by endowment changes according to[11]

$$\widehat{w}_k - \widehat{w}_1 = -\frac{1}{\sigma}\left(\hat{L}_k - \hat{L}_1\right). \tag{14}$$

This begs two questions. First, given the common assumptions, what is the significance of the apparent difference between 13 and 14? And secondly, what is the error that one commits by invoking 13 if there is no common elasticity of substitution in all production and consumption? Turning to the first question, 14 seems more general than 13, in that it does not imply zero cross price elasticities. Indeed, this even makes 13 look a bit counter–intuitive. Once again, however, the clue lies with the normalization chosen. While 14 assumes a common normalization of the price system for both equilibria, thus allowing a change in aggregate expenditure, 13 assumes a constant level of expenditure and hence a re–normalization of prices across equilibria; see appendix A.2. We have already noted above that assuming constant aggregate expenditure $E = 1$ permits a convenient, if somewhat unconventional, interpretation of factor price changes as changes in income distribution.[12]

Regarding the second question, appendix A.2 derives general equilibrium elasticities of aggregate factor demands with respect to factor prices for CES economies with differing elasticities of substitution. Equations 31 and 32 provide some insight into the error committed when wrongly assuming identical elasticities. In particular, holding aggregate expenditure constant no longer assures zero cross price elasticities, thus negating a simple inversion as in 13. The cross price elasticity of aggregate demand for factor k with respect to factor price w_j is nothing but a weighted average of the deviations of substitution elasticities

[11] Panagariya deals with two factors. This equation frames Panagariya's result for two arbitrary factors out of several.

[12] See the discussion following equation 11. We may also add that, with $E = 1$, the income accruing to a factor which increases in supply, expressed as a share of aggregate expenditure, changes according to $\widehat{w}_k + \hat{L}_k = 1 - 1/\sigma$. It falls (rises) if the elasticity of substitution is below (above) unity.

in production from the substitution elasticity in demand, multiplied by the cost shares of factor j, with the sectoral employment shares for factor k serving as weights. Analogous terms also appear in the own price elasticities, alongside the weighted average of the various substitution elasticities in production. There is thus some scope for different errors offsetting each other. But barring without further information on the relevant shares and elasticities, this is probably not something one wants to rely upon.

3 THOUGHT EXPERIMENTS

3.1 The questions asked

I have argued above that invoking thought experiments, instead of investigating historical situations, might be a useful way to exploit the information content of factor contents. How might such thought experiments look like? Deardorff and Hakura (1994) present a general discussion of wage movements and their relationship to trade which is a useful point of departure for our present purpose. They suggest that the following questions might be asked:

1. How does a reduction of trade barriers affect wages?
2. How do changes abroad affect wages through trade?
3. How do wages respond to changes in domestic conditions, or to foreign conditions, or to a given mixture of both, if trade is allowed to change too, as opposed to when trade is held fixed?
4. How do wages respond to any exogenous change if international prices are held constant, as opposed to allowing price adjustments.

Panagariya (1998) complements this classification by making a distinction between I) the impact of trade on wages in a given period, and II) the contribution of trade to the change in wages between two periods. All of these cases envisage some change. A crucial question now is whether or not these are strictly *historical changes.* If so, the likelihood of changes in many dimensions (endowments, tastes, technology) is of course quite large, and the above discussion suggests factor contents will be of only limited use, if at all. However, by invoking certain *counterfactual equilibria* we may succeed in avoiding some of the problems encountered above, and factor contents may turn out to be a useful tool of analysis.

Question 3 is the one that comes closest to the way many people think about the effects of globalization, the principal concern being that economies heavily exposed to trade react differently to just about any exogenous change than do economies that are almost closed to trade. Suppose, then, some arbitrary exogenous change has driven the economy from equilibrium 1 to equilibrium 2. We assume both equilibria are fully observed, including, in particular, $\mathbf{w}_1$ and $\mathbf{w}_2$. Notice that we do not worry about the distinction between exogenous changes in domestic and foreign conditions, as in question 2. Instead, we try to isolate the role that trade, or openness of the economy, plays in the way that exogenous changes of whatever nature are channeled through to wage effects. This can be accomplished by constructing counterfactual equilibria.

For instance, in line with Deardorff and Hakura, we may envisage an equilibrium $\bar{2}$ where all exogenous variables are as in equilibrium 2, "but for" some government policy instruments forcing trade to $\mathbf{T}_1$ instead of $\mathbf{T}_2$. If we can calculate $\widetilde{\mathbf{V}}_2$ and $\widetilde{\mathbf{V}}_{\bar{2}}$ according to 8, we may rely on above arguments to infer $\mathbf{w}_{\bar{2}} - \mathbf{w}_2$ from $\widetilde{\mathbf{V}}_{\bar{2}} - \widetilde{\mathbf{V}}_2$, and $\mathbf{w}_{\bar{2}} - \mathbf{w}_1$ then gives the answer to question 3. Equivalently, we may envisage a decomposition of the actual change:

$$\mathbf{w}_2 - \mathbf{w}_1 = (\mathbf{w}_2 - \mathbf{w}_{\bar{2}}) + (\mathbf{w}_{\bar{2}} - \mathbf{w}_1), \qquad (15)$$

where the first component is the trade–induced wage effect and the second is viewed as not related to trade. It is worth pointing out the difference to the approach commonly used in the literature to separate trade from technology as a source of wage movement, which was criticized on page 19 above. That approach involves trying to explain observed wage changes by observed trade changes and then attributing the unexplained residual to technology. By way of contrast, here we infer what factor prices would have been with a certain counterfactual trade pattern, calling the difference to observed factor prices a trade-induced effect. It is quite clear that the usefulness of this approach critically hinges on the precise interpretation of the counterfactual trade pattern. I shall return to this below. A further point worth emphasizing is that by construction of the thought experiment endowments, technology and tastes are the same in equilibrium 2 and $\bar{2}$, hence we have $\widetilde{\mathbf{V}}_{\bar{2}} - \widetilde{\mathbf{V}}_2 = -\left(\widetilde{\mathbf{F}}_{\bar{2}} - \widetilde{\mathbf{F}}_2\right)$, and if we are willing to assume CES we can even compute the desired wage effect from factor contents alone, as indicated above.[13]

In 15 wage movements that would have occurred with trade held at $\mathbf{T}_1$ are attributed to non–trade causes, defining the remainder as a trade–related effect. There is some plausibility to this, but it begs two questions. First, what, precisely, is the interpretation of a counterfactual equilibrium where exogenous variables are as in situation 2, but where trade is $\mathbf{T}_1$. As will be shown in the next subsection, for question 3 to be well defined, one has to be precise about the kind of exogenous variable that one assumes to adjust such that $\mathbf{T}_1$ is an equilibrium trade vector. And secondly, the procedure involves a fair amount of arbitrariness. Why not extend the "but for" idea to trade as such and do so not only for situation 2, but for the initial equilibrium 1 as well? We then have counterfactual equilibria $\bar{1}$ and $\bar{2}$ where all exogenous variables are as in situation 1 and 2, respectively, but where there is no trade at all. $\mathbf{w}_1 - \mathbf{w}_{\bar{1}}$ might then be called the trade effect on wages in the initial equilibrium, and the decomposition now emerging is

$$\mathbf{w}_2 - \mathbf{w}_1 = [(\mathbf{w}_2 - \mathbf{w}_{\bar{2}}) - (\mathbf{w}_1 - \mathbf{w}_{\bar{1}})] + (\mathbf{w}_{\bar{2}} - \mathbf{w}_{\bar{1}}), \tag{16}$$

where again the first (bracketed) term is the wage–related effect, and the second is what we treat as not related to trade.[14] Indeed, one might even consider turning the Deardorff-Hakura comparison upside down and define the counterfactual $\bar{1}$ as arising if a suitable trade policy had ensured trade to be $\mathbf{T}_2$, with all exogenous variables as in the factual equilibrium 1. Setting $\mathbf{w}_{\bar{2}} = \mathbf{w}_2$, the decomposition then becomes

$$\mathbf{w}_2 - \mathbf{w}_1 = (\mathbf{w}_{\bar{1}} - \mathbf{w}_1) + (\mathbf{w}_2 - \mathbf{w}_{\bar{1}}). \tag{17}$$

With this interpretation, we are looking at factor price changes that would have been observed with the initial exogenous variables except for some special

[13] This assumes that trade per se has no influence on endowments, tastes, and technology. See Panagariya (1998) for further elaborations on trade–induced changes in these variables.

[14] Panagariya (1998) favors 16, but our analysis suggests that there is nothing particularly compelling about this choice. Krugman (1995) also alludes to a thought experiment relying on an autarky equilibrium.

influence that has caused trade to change from $\mathbf{T}_1$ to $\mathbf{T}_2$, which is the first term in 17. This is treated as the trade–induced part of factor price movements, and the remainder is again viewed as not related to trade.

Note that in all cases considered historical equilibria are compared with *contemporaneous* counterfactual equilibria. This is crucial, since it avoids movement across time when exploiting the information content of factor contents, thus escaping many of the problems considered in the previous section. While the construction of a full decomposition along the lines suggested does require further historical observations, this can be accomplished without any further application of factor contents across time. More specifically, for decomposition 15 we start with an *observation* of $\mathbf{w}_2$ from which we *infer* $\mathbf{w}_{\bar{2}}$, relying on calculations of $\widetilde{\mathbf{V}}_{\bar{2}} - \widetilde{\mathbf{V}}_2$ using factor contents. Once we have inferred $\mathbf{w}_{\bar{2}}$, the decomposition is completed by *observing* $\mathbf{w}_1$. In other words, if factor contents can be used to isolate the trade effect on wages at any given point in time, one can also decompose changes across time into a trade–related and a non–trade–related part; see also Panagariya (1998). However, this is possible only if we can fully observe the two relevant equilibria, including factor prices.

3.2 How should we interpret the counterfactuals?

All of the above thought experiments amount to fixing a variable that we normally view as endogenous, viz. trade. This implies that other variables that we normally treat as exogenous must change accordingly so as to support the desired trade vector as an equilibrium. So far, we have loosely alluded to exogenous government policy. But for the thought experiments to be well defined, we must be more precise. The following table clarifies the distinction between the equilibria involved, where we use the short–hands $\mathbf{R}_s$ and $\mathbf{G}_s$ to denote the exogenous variables that are, or aren't, subject to the kind of policy discretion that we have in mind when talking about a special influence forcing trade to some prespecified vector $\mathbf{T}_s$ in situation s.

Variables	Equilibrium			
	1	$\bar{1}$	2	$\bar{2}$
endog. (prices)	$\mathbf{p}_1, \mathbf{w}_1$	$\mathbf{p}_{\bar{1}}, \mathbf{w}_{\bar{1}}$	$\mathbf{p}_2, \mathbf{w}_2$	$\mathbf{p}_{\bar{2}}, \mathbf{w}_{\bar{2}}$
endog. (quantities)	$\mathbf{C}_1, \mathbf{Q}_1, \mathbf{T}_1$	$\mathbf{C}_{\bar{1}}, \mathbf{Q}_{\bar{1}}, \mathbf{T}_{\bar{1}}$	$\mathbf{C}_2, \mathbf{Q}_2, \mathbf{T}_2$	$\mathbf{C}_{\bar{2}}, \mathbf{Q}_{\bar{2}}, \mathbf{T}_{\bar{2}}$
exogenous	$\mathbf{G}_1$	$\mathbf{G}_1$	$\mathbf{G}_2$	$\mathbf{G}_2$
policy	$\mathbf{R}_1$	$\mathbf{R}_{\bar{1}}$	$\mathbf{R}_2$	$\mathbf{R}_{\bar{2}}$

The Deardorff–Hakura exercise (decomposition 15) has $\mathbf{T}_{\bar{1}} = \mathbf{T}_1$ and, therefore, $\mathbf{R}_{\bar{1}} = \mathbf{R}_1$, while setting $\mathbf{T}_{\bar{2}} = \mathbf{T}_1$, with the policy variable $\mathbf{R}_{\bar{2}}$ adjusting accordingly, so as to support $\mathbf{T}_1$, given $\mathbf{G}_2$. In turn, the Panagariya experiment (decomposition 16) sets $\mathbf{T}_{\bar{1}} = \mathbf{T}_{\bar{2}} = \mathbf{0}$, again with appropriately adjusted policy variables $\mathbf{R}_{\bar{1}}$ and $\mathbf{R}_{\bar{2}}$. Finally, decomposition 17 requires $\mathbf{T}_{\bar{1}} = \mathbf{T}_2$ and $\mathbf{T}_{\bar{2}} = \mathbf{T}_2$. Indeed, it is only a small step to question 4 above which in effect fixes prices instead of trade in the counterfactual equilibria, but I shall not pursue this any further.

In view of the popularity of what Anderson and Neary (1998) call the "Mercantilist concern with trade volumes", designing a thought experiment by focusing on trade volumes seems a perfectly reasonable approach to design thought experiments. But whatever the trade volume chosen to construct the counterfactual equilibrium, a crucial question is what kinds of hypothetical policy instruments we should have in mind when treating the trade volume $\mathbf{T}_{\bar{s}}$ *as an equilibrium* based on exogenous variables $\mathbf{G}_s$. In other words, what, exactly, is the difference between policies $\mathbf{R}_s$ and $\mathbf{R}_{\bar{s}}$? There will normally be several policies leading to a given trade vector $\mathbf{T}_{\bar{s}}$, not all of which will give rise to the same factor prices. To see this, consider achieving a specified trade pattern $\mathbf{T}_{\bar{s}}$ for a small economy by means of consumption taxes/subsidies, coupled with a suitable expenditure policy, as opposed to using tariffs which also affect producer prices. There will be different factor prices although in both cases trade is at $\mathbf{T}_{\bar{s}}$. Notice that this even holds true for the case where we set $\mathbf{T}_{\bar{1}} = \mathbf{T}_{\bar{2}} = \mathbf{0}$. Invoking autarchy, i.e., assuming closed borders, is perhaps the easiest or most natural, but by no means the only way to think about zero trade. More generally, whatever the trade vector $\mathbf{T}_{\bar{s}}$, to have a well defined question we need to be more precise about the government policy that makes it a counterfactual *equilib-*

rium trade vector. Given the concern addressed, a natural candidate, of course, is trade policy.[15] But this may not be enough. Even if we stick to perfect competition and ad–valorem tariffs, in the general case of a large number of goods there might be several different tariff schedules leading to the same volume of trade. For simplicity, assume we are looking at a small economy. Suppose that $\mathbf{X}_s(\mathbf{p})$ is the (vector–valued) general equilibrium excess supply function for this economy, given exogenous variables $\mathbf{G}_s$. Since $\mathbf{p} = \mathbf{p}^* + \mathbf{t}$, fixing trade at $\mathbf{T}_{\bar{s}}$ implies tariff equivalents $\mathbf{t}_{\bar{s}}$ which satisfy

$$\mathbf{X}_s(\mathbf{p}_s^* + \mathbf{t}_{\bar{s}}) = \mathbf{T}_{\bar{s}}. \tag{18}$$

For an arbitrary trade vector it is not clear, a priori, if such tariff equivalents do exist, but if $\mathbf{T}_{\bar{s}}$ is not too different from $\mathbf{T}_s$ one may be willing to assume they do.[16] But even so, $\mathbf{t}_{\bar{s}}$ may not be unique. If so, different sets of tariffs compatible with an equilibrium trade vector $\mathbf{T}_{\bar{s}}$ will in general lead to different factor prices. We thus face the uneasy fact that in general there is no one–to–one relationship between the trade vectors $\mathbf{T}$ and the factor price vectors $\mathbf{w}$ in the above counterfactual equilibria $\bar{1}$ and $\bar{2}$. Hence, question 3, in general does not permit a clear–cut answer. For the above thought experiments to be well defined, the trade policies envisaged to support a counterfactual trade volume $\mathbf{T}_{\bar{s}}$ need to be specified in sufficient detail. Notice, however, that all of this leaves the information content of factor contents as such unharmed. Whatever the precise policy behind $\mathbf{T}_{\bar{1}}$, and the prices $\mathbf{w}_{\bar{1}}$ associated with it, it still remains true that an economy with endowment $\widetilde{\mathbf{V}}_{\bar{1}}$ as in 8, if left in isolation, would reproduce these prices as an autarchy equilibrium.[17]

3.3 Calculation

A final point relates to practical problems of calculating factor contents. Since we do not know $\mathbf{w}_{\bar{s}}$ – indeed, we want to infer $\mathbf{w}_{\bar{s}}$ from factor contents – we also

[15] This trade policy interpretation of a counterfactual was suggested by Deardorff (1997). An application following this idea is Baldwin and Cain (1997).

[16] Moreover, it should be noticed that arbitrarily fixing net trade at given international prices $\mathbf{p}_s^*$ may involve unbalanced trade, except for coincidence. Hence, if we want to interpret $\mathbf{t}_{\bar{s}}$ as tariff policy, this must be supported by a suitable expenditure policy guaranteeing $\mathbf{p}_s^{*\prime}(\mathbf{Q}_{\bar{s}} - \mathbf{C}_{\bar{s}}) = \mathbf{p}_s^{*\prime}\mathbf{T}_{\bar{s}}$.

[17] See the discussion following equation 8 above.

do not know the appropriate matrix $\mathbf{A}_{\bar{s}}$ to be used for calculating $\widetilde{\mathbf{F}}_{\bar{s}}$ according to equation 6. Only for Leontief technologies we may use $\mathbf{A}_s$ to calculate $\widetilde{\mathbf{F}}_{\bar{s}}$. In this case, $\widetilde{\mathbf{V}}_{\bar{s}}$ in 8 is the same regardless of the policy underlying $\mathbf{T}_{\bar{s}}$,and issues of calculation place no further restriction on the design of thought experiments. In all other cases the factor prices determined by a specific trade policy would be reflected in the associated input matrix $\mathbf{A}_{\bar{s}}$. Being counterfactual, however, this is non–observable, and using $\mathbf{A}_s$ instead involves a measurement error which needs to be taken into consideration. Fortunately, this problem does not arise for decomposition 16, where the counterfactual equilibria $\bar{1}$ and $\bar{2}$, respectively, are the autarchy equilibria. For in this case, since $\mathbf{T}_{\bar{s}} = \mathbf{0}$, $\widetilde{\mathbf{F}}_{\bar{s}} = \mathbf{0}$ as well, whatever the relevant coefficients $\mathbf{A}_{\bar{s}}$.

4 SUMMARY AND CONCLUSIONS

Trade and wages are both endogenous variables. Exploring a relationship between the two makes sense only if the "natural" approach for some reason is not feasible, which would be to construct an explicit model of how trade and wages are jointly determined by exogenous forces, and to implement this model empirically in order to find out which of these forces was dominant in certain periods in time. However, very often in the context of globalization scenarios, explicitly modeling the exogenous changes is impossible because they are too large in number, too complicated, or because one doesn't even have a clear notion of what they are. Under such circumstances, resorting to factor contents of trade may be an alternative approach worth pursuing. But the information that may be extracted from factor contents is rather limited, the assumptions necessary to do so are quite restrictive, and, depending on the precise circumstances, additional observations may be required to obtain any information at all.

It is generally important to separate the following two issues. a): If $\widetilde{\mathbf{F}}_1$ and $\widetilde{\mathbf{F}}_2$ are the factor content vectors of two arbitrary trading equilibria, how are they related to the corresponding factor price vectors $\mathbf{w}_1$ and $\mathbf{w}_2$? And b): How may we define $\widetilde{\mathbf{F}}_1$ and $\widetilde{\mathbf{F}}_2$ in a given empirical context in order to learn interesting things about factor prices that we cannot observe otherwise.

Factor contents do not allow any inference on changes in the well–being of factor owners, but only on changes in the functional distribution of real income. Given the heavy emphasis on income distribution in the current discussion on globalization, this may not be much of a restriction, but it is nonetheless an important point which needs to be duly observed when interpreting empirical results. The precise way in which distribution effects may be inferred is governed by the normalization assumptions on the price system which are necessary to pin down the relationship between factor contents and factor prices, Moreover, in general inference on income distribution is only possible in the weak sense of a summary measure of the direction in which relative factor prices have been influenced by the exogenous change in question. Focusing on individual factor prices requires further specific assumptions regarding the elasticities of substitution in the underlying technology and in preferences. Whether or not additional information, as for instance on domestic endowment changes or technology, is necessary to arrive at a reasonably safe conclusion very much depends on the specific thought experiment in which factor contents are employed. Hence the importance of separating a) from b). Such thought experiments may be designed in various different ways for a given historical episode under investigation, and one may conceivably do so in such a way that no additional information is needed for a useful interpretation of factor contents.

Technological change may play a role in two ways. It may be an analytical vehicle through which specialization effects are brought into the picture, or it may be technological change proper. Specialization effects can be shown in general to be "friends" to those factors intensively used in commodities that are in turn favored by a high elasticity of substitution in demand. If a completely unspecified technological change proper is present, then factor contents have no information content whatsoever, and any attempt to attribute residual factor price changes that cannot be explained by observed factor contents is without theoretical foundation. When specific technological changes are contemplated in connection with the factor contents approach, then, contrary to widespread habit, the appropriate perspective is that of a closed economy.

A suggestive way to construct thought experiments that usefully rely on factor contents is to focus on counrterfactual trade volumes, i.e., a benchmark net trade vector which differs from the one observed in a given historical situation. For a correct interpretation of factor contents it is vital to have a clear understanding of these counterfactuals. We have offered a useful classification and precise interpretations of the counterfactual equilibria involved. These invariably imply that variables which are normally treated as exogenous switch their roles and become endogenous in the sense of supporting (in the sense of a general equilibrium) the counterfactual trade vector. An obvious candidate for exogenous variables becoming endogenous in this way are hypothetical trade policy measures. A crucial question then is what kind of trade policy measures. This needs to be answered unambiguously for the counterfactuals to be clearly defined.

Is there a final verdict on the role of factor contents in answering important questions about the effects of globalization? Delivering such a verdict was not my intention in this paper. There is certainly no easy and straightforward way to apply factor contents to the globalization debate. But I have tried to argue that dismissing them outrightly seems premature. Given the available alternatives under specific circumstances, one may venture to design specific thought experiments, in which the information content that factor contents do have may be brought to bear on important issues of globalization.

A APPENDIX

A.1 Factor contents and factor prices with changing endowments

The traditional approach due to Deardorff & Staiger relies on the relationship between differences in factor endowment and associated differences in factor prices for a closed economy, using factor contents to calculate hypothetical closed economy factor contents. In applications across time this requires that actual factor endowments remain constant. An alternative is to focus more directly on the relationship between factor price differences and bilateral factor contents in the presence of international endowment differences, as explored by Helpman (1984). The purpose of this appendix is to investigate if this approach leads to useful interpretations of factor contents for comparisons across time, as usually emphasized in the trade and wages literature. It draws on certain properties of the profit function $\Pi(\mathbf{p}, \mathbf{V})$ which gives the maximum value of output that an economy may produce given prices $\mathbf{p}$, its primary factor endowment $\mathbf{V}$, and a constant returns to scale technology. This function is convex in $\mathbf{p}$ and concave in $\mathbf{V}$. Consider two equilibria $\{\mathbf{p}_1, \mathbf{V}_1\}$ and $\{\mathbf{p}_2, \mathbf{V}_2\}$. Following Helpman (1984, appendix), we may write concavity in $\mathbf{V}$ as:

$$\Pi(\mathbf{p}_1, \lambda_2\mathbf{V}_2) \leq \Pi(\mathbf{p}_1, \lambda_1\mathbf{V}_1) + \mathbf{w}_1'(\lambda_2\mathbf{V}_2 - \lambda_1\mathbf{V}_1) \tag{19a}$$

$$\Pi(\mathbf{p}_2, \lambda_1\mathbf{V}_1) \leq \Pi(\mathbf{p}_2, \lambda_2\mathbf{V}_2) + \mathbf{w}_2'(\lambda_1\mathbf{V}_1 - \lambda_2\mathbf{V}_2) \tag{19b}$$

If the profit function is differentiable at $\{\mathbf{p}_1, \lambda_1\mathbf{V}_1\}$, then $\mathbf{w}_1 = \Pi_\mathbf{V}(\mathbf{p}_1, \lambda_1\mathbf{V}_1) = \Pi_\mathbf{V}(\mathbf{p}_1, \mathbf{V}_1)$ where the latter equality follows from zero degree homogeneity of $\Pi_\mathbf{V}$,and analogously for $\mathbf{w}_2$. If it is not differentiable, factor prices are not uniquely determined by the profit function, but they must still support the profit function from above.

By complete analogy, we write convexity in $\mathbf{p}$ as

$$\Pi(\mathbf{p}_2, \lambda_1\mathbf{V}_1) \leq \Pi(\mathbf{p}_1, \lambda_1\mathbf{V}_1) + \lambda_1\mathbf{Q}_1'(\mathbf{p}_2 - \mathbf{p}_1) \tag{19c}$$

$$\Pi(\mathbf{p}_1, \lambda_2\mathbf{V}_2) \leq \Pi(\mathbf{p}_2, \lambda_2\mathbf{V}_2) + \lambda_2\mathbf{Q}_2'(\mathbf{p}_1 - \mathbf{p}_2) \tag{19d}$$

Here we have exploited linear homogeneity of the profit function in endowments. Moreover, we have used $\mathbf{Q}_1 = \Pi_\mathbf{p}(\mathbf{p}_1, \mathbf{V}_1)$, given differentiability, and the previous remarks apply mutatis mutandis.

If $\mathbf{p}_1 = \mathbf{p}_2$ equations 19a and 19b imply

$$(\mathbf{w}_2 - \mathbf{w}_1)' (\lambda_2 \mathbf{V}_2 - \lambda_1 \mathbf{V}_1) \leq 0 \tag{20}$$

This is the result that Helpman derives comparing countries. Here, we can interpret it for a given country across two trading equilibria. Given constant commodity prices, a change in factor prices can only occur if this country moves from one diversification cone to another. If this happens factor price changes and endowment changes satisfy inequality 20. Notice that so far there is no restriction on price normalization. Using 7 we may rewrite inequality 20 as

$$\begin{aligned}(\mathbf{w}_2 - \mathbf{w}_1)' \left(\lambda_2 \widetilde{\mathbf{F}}_2 - \lambda_1 \widetilde{\mathbf{F}}_1\right) \leq \lambda_2 &\left(\mathbf{w}_2' \widetilde{\mathbf{F}}_2^C - \mathbf{w}_1' \widetilde{\mathbf{F}}_1^C\right) \\ &- \lambda_1 \left(\mathbf{w}_2' \widetilde{\mathbf{F}}_1^C - \mathbf{w}_1' \widetilde{\mathbf{F}}_1^C\right). \end{aligned} \tag{21}$$

We are now free to choose positive λ's plus a suitable price normalization. We may imagine using these degrees of freedom to ensure that the right hand side is zero. But the question is can we do so by choosing a normalization which permits an intuitive interpretation of factor price changes (for instance $\mathbf{w}_2' \widetilde{\mathbf{F}}_2^C = 1$ and $\mathbf{w}_1' \widetilde{\mathbf{F}}_1^C = 1$, as in the DS result above), while at the same time ensuring positive λ's. Even if this can be done, we would still be left with "weights" λ_1 and λ_2 attached to the factor contents of trade which are functions of the normalization chosen, and which are also dependent on factor prices. This effectively negates any empirical application.

If $\mathbf{p}_1 \neq \mathbf{p}_2$ we may combine the above inequalities to arrive at a restriction analogous to 21, with $\mathbf{w}_2' \widetilde{\mathbf{F}}_2^C$ replaced by $\mathbf{p}_2' \mathbf{Q}_2$, and analogously for all other terms on the right hand side. The conclusion reached in the preceding paragraph carries over as well.

A.2 Factor prices and factor demands under CES

In one way or another, the empirical literature on trade and wages has assumed that elasticities of aggregate factor demands may be employed to infer factor price changes from factor supply changes which have, in turn, been calculated using, among other things, factor contents. Given the specific interpretation of factor contents, these would have to be *general equilibrium* elasticities for *closed* economies. Unless economies are characterized by a common elasticity of substitution in all demand and production, such elasticities will heavily depend on sectoral detail. This appendix derives general equilibrium elasticities of factor demands for an arbitrary number of goods and factors under the assumption that preferences and production feature CES, but with different elasticities of substitution. Following common practice, we use

λ_{ki} to denote the share of factor k employed in sector i, with $\sum_i \lambda_{ki} = 1$, with matrix notation Λ,and

θ_{ik} to denote the cost share of factor k in the production of good i, with $\sum_k \theta_{ik} = 1$.

Under CES preferences, demand for commodity i is

$$C_i = \alpha_i \left(p_i/E\right)^{-\gamma}, \tag{22}$$

where γ is the constant elasticity of substitution and α_i is a constant parameter indicating the "importance" of good i in consumption. E is expenditure as defined in 5. In turn, if η_i is sector i's elasticity of substitution in production, demand for factor k in sector i is

$$l_{ik} = \beta_{ik} w_k^{-\eta_i} \left[c_i(\mathbf{w})Q_i\right]^{\eta_i}, \tag{23}$$

where $c_i(\mathbf{w})$ is the minimum unit cost in this sector, given factor prices $\mathbf{w}$, while β_{ik} is a parametric factor intensity term. Autarchy equilibrium requires $Q_i = C_i$ and $c_i(\mathbf{w}) = p_i$. We have

$$\hat{c}_i = \hat{p}_i = \sum\nolimits_k \theta_{ik} \hat{w}_k. \tag{24}$$

Due to Sephard's Lemma, the elasticity of $c_i(\mathbf{w})$ with respect to factor price w_k is θ_{ik}.

Following Jones and Scheinkman (1977), we may write the differentiated full employment conditions in matrix form as

$$\Psi \hat{\mathbf{w}} + \Lambda \hat{\mathbf{Q}} = \hat{\mathbf{V}}, \tag{25}$$

where the element ψ_{kj} of Ψ gives the elasticity of *total* factor k use with respect to a change in factor price w_j at constant outputs. The second term on the left captures the effects of output changes on factor demand. Λ is the matrix representation of factor allocations λ_{ki} as defined above. Given the above factor demands, we have

$$\psi_{kk} = \sum\nolimits_i \lambda_{ki} (\theta_{ik} - 1) \eta_i, \quad (26a)$$

$$\psi_{kj} = \sum\nolimits_i \lambda_{ki} \theta_{ij} \eta_i. \quad (26b)$$

Given the above demand functions 22 and 23, and bearing in mind our normalization $E = 1$, for a closed economy we have

$$\begin{aligned} \hat{Q}_i &= -\gamma \hat{p}_i \\ &= -\gamma \sum\nolimits_k \theta_{ik} \hat{w}_k. \end{aligned} \quad (27)$$

With this in mind, we can write

$$\Lambda \hat{\mathbf{Q}} = \Omega \hat{\mathbf{w}}, \quad (28)$$

where the elements of the matrix Ω are

$$\omega_{kj} = -\sum\nolimits_i \lambda_{ki} \theta_{ij} \gamma. \quad (29)$$

Equation 25 now emerges as

$$(\Psi + \Omega) \hat{\mathbf{w}} = \hat{\mathbf{V}}. \quad (30)$$

Exploring the properties of $\boldsymbol{\phi} = \Psi + \Omega$, we see that

$$\phi_{kk} = -\sum\nolimits_i \lambda_{ki} \eta_i + \sum\nolimits_i \lambda_{ki} \theta_{ik} (\eta_i - \gamma), \quad (31)$$

$$\phi_{kj} = \sum\nolimits_i \lambda_{ki} \theta_{ij} (\eta_i - \gamma). \quad (32)$$

These are the general equilibrium elasticities of total demand for factor k with respect the price of factor j. Notice that ϕ_{kk} is always negative, while the individual cross price elasticities are unclear in sign. The special case where $\eta_i = \gamma = \sigma$ implies $\phi_{kk} = -\sigma$ and $\phi_{kj} = 0$ and gives rise to equation 13. In the more general case the usual procedure of inferring factor price changes from supply changes through an inversion of 30 is no longer straightforward.

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