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Factor Price Equalization: Theory and Evidence

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Abstract

Students of international economics have absorbed the factor price equalization (FPE) theorem over recent decades. It may be time to reconsider that factor prices would likely converge outside the context of the formal Heckscher-Ohlin-Lerner-Samuelson model. This paper reviews the theoretical evolution of FPE and the empirical evidence regarding the influence of trade on the international pattern of factor prices.

I. Introduction

This paper examines the status of factor price equalization (FPE) as a scientific hypothesis. Every college student of international economics is exposed to FPE in one form or another. International trade theorists doing research in competitive models typically accept FPE as a paradigm and favor free trade. Trade theorists doing research in strategic models of imperfect competition seem less inclined to do either. Ultimately, empirical tests of FPE should carry the day.

The first section of this paper reviews the theoretical background of FPE and notes the tendency for trade to cause factor price convergence (FPC) outside the

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context of the Heckscher-Ohlin-Lerner-Samuelson (HOLS) model. Next, there is an account of the blossoming empirical literature on FPE. Short sections on policy implications and suggestions for further research complete the review. At stake is nothing less than one of the fundamental propositions and basic paradigms of international economics.

II. Theoretical Background of FPE

Heckscher [1919] is the first economist to argue that under certain conditions international trade would lead to complete equalization of prices of similar factors across countries. Heckscher identified identical production techniques as the key condition for equalization of factor prices. Difference in factor prices, he argued, would be a *sufficient cause* for international trade if production techniques were the same everywhere, and trade would then equalize returns to similar factors across countries.

Although Heckscher mentioned other assumptions, he did not present a complete list because his treatment was informal. As a result, he left out some of the typical sufficient conditions for FPE. For example, he did not consider the numbers of factors and international markets (goods) critical to the argument. Heckscher in fact uses a 3×2 *classical* model with three factors (labor, capital, land) and two goods (textiles, machinery). Trade theorists now know that in such an *uneven* model, if factors are immobile and goods perfectly mobile internationally, FPE does not hold. Nevertheless, Heckscher is rightfully credited for having the original insight into a proposition that has become one of the core propositions of international economics.

Heckscher's student Ohlin elaborates on FPE in his 1924 doctoral dissertation, which evolved into the longer version *Interregional and International Trade* [1933]. Ohlin's thesis is that international trade can substitute for factor movements, causing partial equalization of factor prices. Curiously enough, Ohlin presents his analysis using a 2×2 model in which complete FPE is possible. Flam and Flanders [1991] have translated and published the works of Heckscher and Ohlin from Swedish into English.

FPE, as we know it now, was crafted in two papers by Samuelson [1948, 1949]. By demonstrating complete FPE, Samuelson moved beyond the partial equalization implied by the Stolper-Samuelson article in 1941. Jones [1988, p. 621] discusses

this point. Samuelson's FPE articles reminded Robins of a seminar paper that Lerner, as a student, had presented in 1933 at the London School of Economics. Lerner [1952] recreates that paper and clearly lays out sufficient conditions for FPE in the 2×2 model.

The heart of FPE in competitive general equilibrium models is an invertible mapping from the vector of prices p to the vector of factor prices w. Under some conditions, prices of goods uniquely determine prices of productive factors. The general equilibrium FPE literature is rich, vast, and varied: Samuelson [1953, 1967, 1971], McKenzie [1955], Johnson [1957], Lancaster [1957], Uzawa [1959], Chipman [1966], Bhagwati and Srinivasan [1971], Kuga [1972], Nikaido [1972], Balassa [1974], Joshi [1987], McMahon [1988], and others. Controversy over FPE surfaced early, as exemplified by Pearce and James [1951] and Pearce [1952]. When free trade equalizes the price of each good between trading nations, equal international prices of the same productive factors are implied if the mapping from p to w is singular.

The formal proof of FPE is based on a neoclassical production structure with two final traded goods and two primary domestic factors of production in the HOLS model. Extension to models with more goods, more factors, nontraded goods, internationally supplied factors, and market imperfections are built upon the HOLS model. With competitive pricing, the price of a good (p_j) equals its average cost of production (c_j). In the background, not modelled explicitly, must be a process of entry and exit which forces average cost to equal price. Firms in each industry minimize cost by choosing inputs to produce a profit maximizing output, given exogenous (to the firm) factor prices. Cost minimization is a key link in the FPE argument. Competitive pricing is not necessary for cost minimization, suggesting FPE could occur outside the context of competitive pricing.

Prices of the final traded goods are assumed exogenous at world levels, the small country assumption. The null hypothesis of the small country assumption has not been freely rejected in the few empirical tests to date. A country loses market power as the degree of aggregation increases. If a factor price is given at the world level, the economy is a price taker in that international factor market. The immediate effect of exogenous prices, either of goods or productive factors, is to reduce the degrees of freedom in the general equilibrium model.

The critical condition for FPE is deceptively simple: the number of factors must not be greater than the number of international market (exogenous prices) as

developed by Samuelson [1953], Jones and Scheinkman [1977], and Ethier and Svensson [1986]. If the number of factors is greater than the number of exogenous prices, FPE does not follow since different vectors w of factor prices support the competitive equilibrium. Trade theorists typically avoid the situation of more factors than international markets, although it has not been eliminated on empirical grounds. According to tests of separability, the number of factors is evidently quite large. Clark, Hofler, and Thompson[1988] point out that US manufacturing has at least eight types of labor which cannot be consistently aggregated in any way.

If the number of international markets is greater than the number of factors, the competitive model is overdetermined and some industries will shut down. This situation is described by Johnson [1967, 1970], Bertrand [1970], Rader [1979], and Wu [1987]. The classic example is the complete specialization which occurs in a Ricardian constant cost economy in which two traded goods are produced with a single domestic factor.

Another implicit assumption is that there is no joint production. Each of the finished goods is produced via an independent production function. Joint production (gas and heating oil, for example, as outputs of oil refining) is similar to disaggregating finished goods in its effects on the mapping from prices to factor prices. If all goods are traded and the number of goods (nonjoint plus joint) exceeds the number of factors, the model is overdetermined. Samuelson [1992] and Jones [1992] address the issue of joint production in models of production and trade.

A. FPE in the 2×2 HOLS Model

A picture of cost minimization for a two sector economy is presented in the Lerner-Pearce diagram of Figure 1. Inputs of factors 1 and 2 are measured along either axis. Unit value isoquants are labelled x_j ($j = 1, 2$). Smooth convex unit value isoquants represent amounts of the two factors of production required to produce one dollar's worth ($1/p_j$) of either good. Prices of goods are fixed at exogenous world levels. Suppose further that production functions are identical across countries, a strenuous assumption considering the literature on applied production analysis. Each unit value isoquant would then be identical for each of the trading partners.

Productive factors are freely mobile between sectors, which implies each factor price (w_i) will be the same across sectors. Firms in each industry will produce

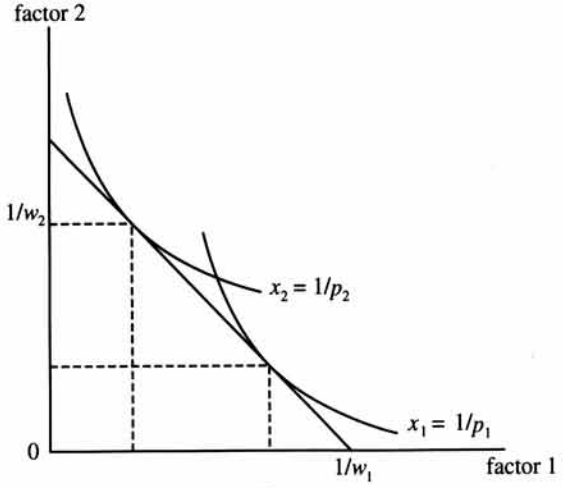

Figure 1

where the unit value isoquant is supported by an isocost line. With both industries employing both factors, a common isocost line must support both unit value isoquants. The common unit isocost line is written

$$c_j = 1 = \sum_i w_i a_{ij} .$$

Equilibrium is pictured with cost minimizing inputs which are functions of the vector of factor prices: $a_{ij} = a_{ij}(w)$. Factor prices w_1 and w_2 are uniquely determined in the general equilibrium. There is no room for different factor prices and no way for different factor supplies to influence factor prices given this structure of production, evidently even with redundant factor supply in complete specialization.

B. FPE and High Dimensional Models of Production and Trade

Suppose the number r of productive factors is greater than 2 and all factor prices are endogenous. If the number n of goods equals r and all goods are traded at world prices, FPE follows. When $r = n = 3$, for instance, three bowl shaped isoquants are supported by a unique isocost plane.

If $r = 3$ and $n = 2$ as in Heckscher's original model, FPE loses its logical compulsion and technical conditions would determine whether free trade tends to equalize factor prices. Two bowl shaped isoquants rest within the three factor axes. The isocost plane could pivot and remain tangent to the isoquants. Factor prices are not uniquely determined. This theoretical possibility is called factor price polarization

(FPP) by Thompson [1986]. A negative correlation can arise between the price of a good and the price of the factor used most intensively in its production. If all three pairs of factors are technical substitutes, free trade causes factor price convergence (FPC) except in situations of pronounced differences in factor intensity. Both factor substitution and factor intensity play a role in determining the effects of changing prices of goods on factor prices, as described by Jones and Easton [1983] and Thompson [1985a].

Factors in the 3×2 model can be renumbered and unit factor inputs ranked

$$a_{11} / a_{12} > a_{21} / a_{22} > a_{31} / a_{32}.$$

Factor 1 is the extreme factor in sector 1, factor 3 is extreme in sector 2, and factor 2 is the middle factor, using the terminology of Ruffin [1981]. If $\partial w_1 / \partial p_1$ and $\partial w_3 / \partial p_2$ are both positive, FPC would occur and relatively abundant (cheap) factors would enjoy increasing prices with trade. Suppose, on the other hand, conditions favor FPP. If factor 1 is relatively cheap, good 1 should be relatively cheap in autarchy. When trade opens, the price of good 1 rises but the price of extreme factor 1 may fall. Empirical work would either examine technical conditions (substitution elasticities and factor intensities) or look for direct evidence of FPP versus FPC.

If $r = 2$ and $n = 3$, an additional isoquant would be added to Figure 1. Cost minimization in every industry would be impossible unless the three isoquants happened to align, and one industry would generally be forced to shut down. An implication is that as an economy opens to trade and goods switch from being nontraded to traded, industries would shut down. While shutting down may seem farfetched, industries (defined finely enough) regularly do just that. Political opponents to free trade are in fact inclined to stress this point. Land [1959] and Johnson [1967, 1970] explicitly develop the 2×3 model. If one of the three goods is nontraded, its price would adjust so that cost minimization could occur. Rodriguez [1975] and Deardorff and Courant [1990] examine FPE in the presence of a nontraded good.

C. Near FPE

Specifications of general equilibrium models where FPE does not hold suggest that FPE will nearly hold between trading partners. Near FPE (NFPE), developed by Thompson [1990], applies across a wide range of underlying production func-

tions. Elasticities of factor prices with respect to factor endowments, if not zero, are nearly zero. Different endowments across competitive economies would account for only small quantitative differences in factor prices. In the computable general equilibrium (CGE) models surveyed by Shoven and Whalley [1984], the effects of changing endowments on factor prices are consistently small.

An implication of NFPE is that much of the fuss over conditions leading to FPE versus FPC or even FPP may be of little empirical weight. Free trade would at any rate nearly equalize factor prices across economies. The international equalizing of prices of goods has a powerful quantitative influence, which should perhaps come as little surprise. Imagine an economy with 10 productive factors under conditions which lead to FPE. Disaggregating one factor would relax the sufficient conditions for FPE, and the $\partial w / \partial v$ elasticities (where v represents the vector of factor endowments) would no longer be zero. This disaggregation, however, would have only a small quantitative effect on the model's static solution of factor prices.

D. FPE and Exogenous Factor Prices

Suppose the price of one of the factors in Figure 1 is exogenized, with input 1 (capital) bought on an international market at w_1^*. The endpoint $1 / w_1^*$ of the isocost line is fixed. With each of the prices of goods exogenously given, the model is overdetermined in that the arbitrary position of $1 / w_1^*$ may be inconsistent with the two isoquants. If one of the goods were nontraded, its price would be endogenous and the number of factors (two) would equal the number of international markets (one for factor 1 plus one for good 2).

In models with more factors than goods, exogenous factor prices would reduce the degrees of freedom and increase the likelihood of FPE. Institutional forces may exogenize factor prices: labor contracts, subsidized capital returns, and so on. In a model where FPE holds, opening one factor market to an exogenous international price would result in industrial shutdown.

E. FPE and the Specific Factors Model

In the specific factors (SF) model, each sector shares a common factor (labor) while employing a sector specific input (capital). Figure 2 pictures the SF model, with two sets of factor prices for identical unit value isoquants. FPE does not hold

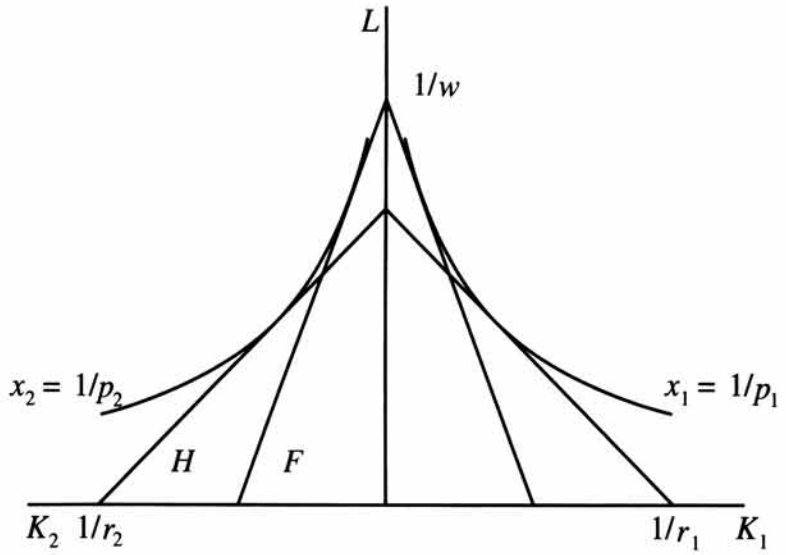

Figure 2

since factor prices depend on factor endowments.

Samuelson [1971] shows that with identical homothetic demand across countries, FPC occurs with free trade. Imagine two SF economies producing the same two goods in autarchy. Assume the only difference between the two countries is that the home country has more sector 1 capital. The relative price of good in the home country would be lower, and the home country would export good 1 when trade opens. With p_1 rising, the return to capital in sector 1 rises. FPC occurs since $\partial r_j / \partial p_j > 0$, where r_j is the return to capital in sector j.

FPC is closely linked with the Heckscher-Ohlin (HO) pattern of trade in the SF model. A rising price for an exported good leads to a higher return to sector specific capital. A country would tend to export goods using specific factors which were relatively abundant (cheap) in autarchy.

The SF model occupies a middle position between the 3×2 model and the 2×2 HOLS model. In the 3×2 model, neither FPE nor FPC is necessary outcome. In the 2×2 model, FPE is necessary. In the SF model, FPC occurs given regular assumptions about demand, but FPE is not a necessary outcome. These relationships generalize to higher dimensional models in a straightforward way.

FPE would be implied in the SF model if one factor were mobile internationally. If capital in one sector comes from an international market, employment of international capital adjusts to clear the model. The cost minimization is then tied to a

unique set of factor prices. The SF model in Figure 2 with international capital leads to FPE as in Srinivasan [1983] and Thompson [1985b].

F. FPE and Aggregation

The FPE argument may hold in higher dimensions for various numbers of factors, goods, and internationally traded factors, as described by Ethier [1974], Chang [1979], Takayama [1982], and Thompson [1983, 1987]. Suppose there are r factors of production, with m of the r factors employed at international prices. If less than $s = r - m$ goods are traded internationally, FPE does not hold and FPC or FPP could be the rule. If s goods are traded internationally, FPE will hold. If more than s goods are traded internationally, industrial shutdown will occur. Viewed from the perspective of aggregation schemes, FPE can be called a razor's edge proposition.

The issue of the number of goods and factors is more than idle academics. Industries and factors of production struggle to establish their economic identity. Aggregation is critical to the FPE argument, as discussed by Hicks [1959], Chipman [1966], and Krueger [1968]. Theoretical investigation comes to the impasse of having to specify a model with a certain number of factors and goods. Leamer [1992a, p. 15] argues that "One rather silly assumption that cries out for change is equal numbers of commodities and factors." Aggregation is the critical process leading to conditions which determine whether to expect FPE, but few researchers are drawn to improve its difficult theory or application. A convenient aggregation scheme is typically chosen to suit the theoretical model with little else for a guide.

A relevant question concerns how much FPE would be relaxed if aggregation is unable to meet strict requirements for FPE to hold. Put another way, how much of the disparity in international wages can be attributed to conditions regarding the numbers of factors and international markets? Tests of a theoretical proposition are implicitly tests of the assumptions implying the proposition. If a theory is rejected, some of the assumption leading to it must be altered and the theory reformulated.

G. FPE and Imperfect Competition

The building blocks of FPE are cost minimization and intersector factor mobility. Competition in the factor markets, more pervasive than competition in output

markets, is fundamental. Models with monopolies, international duopolies, and product differentiation in the output markets have no necessary impact on the FPE argument. In any industrial organization, firms will minimize cost.

Imagine the economy is a single monopolist hiring two factors of production and producing a good which is both consumed at home and exported. The monopolist equates marginal revenue (from foreign and home demand) with marginal cost to maximize profit. Profit is maximized profit by hiring inputs where the marginal rate of technical substitution along the targeted isoquant equals the ratio of factor prices.

In strategic models, Nash or Bertrand equilibria determine output, price and perhaps quality of competing firms. If factor markets are competitive and firms minimize their cost of production with all inputs variable, strategic behavior does not necessarily affect the FPE argument. Strategic models are typically partial equilibrium, while FPE is a general equilibrium result. Games theoretic models would ideally be imbedded in a general equilibrium model which could elucidate income redistribution.

H. Necessary Conditions for FPE

If some goods are traded freely between two countries and FPE holds, some necessary conditions follow. Free trade implies $p_j = p_j^*$ for each traded good, where $*$ represents a foreign variable. FPE implies $w_i = w_i^*$ for each factor. Marginal product (MP) for each factor in producing each good must then be equal across countries. If factors are paid their marginal value or revenue products, $MP_{ij} = MP_{ij}^*$, regardless of the industrial structure.

One test of FPE would be to estimate and compare MPs of the same factor across countries. Over time, MPs should converge. The issue is not whether production functions are identical, but whether MPs at existing input levels are equal (FPE) or converge (FPC). Different production functions for the same good could result in identical MPs. The observation of different wages across countries has no necessary bearing on labor's MPs in the various industries.

I. A General Argument for FPC

FPC is very important as a general working hypothesis. In Ohlin's [1933] informal manner, a compelling argument proceeds from relative factor abundance

to relative factor cheapness and then to relatively cheap goods which use those factor intensively. Hicks [1959, p. 267] argues that FPE could be viewed as a long run tendency. When a country begins to export, demand rises for its relatively cheap goods which are likely cheap because their production relies on relatively cheap factors of production. With the opening of trade, there is an increase in the demand for these abundant and cheap factors used intensively in export production.

Few economists express overwhelming exception to this argument, although there are numerous places where it might go astray and it might not explain every instance of trade. This general argument for FPC lacks logical compulsion but carries weight as a practical guide to understanding the effects of trade. FPC has broad general appeal.

Economists who believe that markets work well (or better than any alternative) believe the general argument that free trade will tend to equalize the return to similar factors internationally. Economists who are suspicious of markets will not trust free trade to create a more equitable international distribution of income. For each group, empirical testing may be more critical than theoretical refinement.

III. Empirical Studies of FPE

FPE would ideally be tested across different countries under various conditions. Scientific opinion would gradually form on one side of the proposition or the other. The FPE theorem would then be generally accepted or rejected. If it were rejected, alternative theories would be formulated and tested in turn. FPE has not received such scientific scrutiny, and has been dismissed offhand by some of the profession.

It is worth noting that of the four propositions of the HOLS model, only the HO trade pattern has been subjected to systematic empirical scrutiny. Bhagwati [1964], Michaely [1964], Stern [1975], and Deardorff [1984] survey the field. The Stolper-Samuelson theorem has been directly tested only by Magee [1989] and Gaston and Trefler [1992]. Papers estimating the effects of protection (or trade liberalization) on wages and income distribution include Evens [1971], Burgess [1976], Hartigan and Tower [1982], and Thompson [1990]. The computable general equilibrium (CGE) literature produces empirical estimates of Stolper-Samuelson comparative static elasticities. The Rybczynski theorem has never been directly tested, but Leamer [1992b] presents some preliminary results.

Systematic empirical work on FPE began during the 1980s. It is curious that FPE

had not previously received empirical attention, especially since the HO and FPE theorems are regarded as two sides of the same coin. Heckscher and Ohlin never treated the two propositions as separate. Much of the subsequent theoretical work considers the two propositions inseparable, as in Minhas [1963] and Jones [1988]. The HO theorem has been tested numerous times since Leontief [1953] and continues to attract empirical attention. For a recent major contribution, see Leamer [1984].

A. Early Pessimism about the Relevance of FPE

A reason for the lack of empirical work on FPE lies in the pessimism that leading trade theorists expressed about its empirical validity. According to Flam and Flanders [1991, p. 9], Heckscher "did not accept factor-price equalization as an empirical fact." Ohlin [1933, p. 26] went further and declared that "Complete equality of factor prices is ... almost unthinkable and certainly highly improbable." In Samuelson [1949], where a rigorous proof of FPE is provided, there is at least mild doubt in its empirical validity. After laying down the assumptions of FPE, Samuelson writes [p. 870] "...our problem is from now on a purely logical one. Is 'If *H*, then inevitably *C*' a correct statement? The issue is not whether *C* (FPE) will actually hold."

Trade literature in the 1960s is replete with negative remarks about the empirical relevance of FPE. Samuelson [1964, p. 152] calls FPE an "unrealistic model," and notes that it requires a production function that "would not seem realistic enough for empirical calculations." Caves [1960, p. 92] offers the following view: "One may well wonder why the arid factor price equalization theorem has attracted so much attention. The whole discussion is, for better or worse, a supreme example of non-operational theorizing." Bhagwati [1964, p. 32] notes, while reviewing FPE: "Although the subject is . . . of historic interest and still continues to attract fresh minds, one cannot help feeling that perhaps too great a proportion of intellectual energy has been directed towards a question of limited utility." Travis [1964, p. 246] comments that "the ability of trade to equalize factor returns and thus to allocate world production optimally is limited, even if transport costs were zero." Kemp [1964, p. 45] expresses the opinion that FPE "is important if only because it focuses attention on the obstacles to equalization."

An empirical study by Minhas [1963] questions the relevance of FPE because of factor intensity reversals (FIRs). Minhas notes that when the elasticity of substitu-

tion between two factors differs across countries, FIRs may occur. After estimating elasticities for several industries, Minhas concludes that FIRs cannot be ruled out. Minhas points out that the same set of commodity prices can be consistent with different factor price ratios in the presence of FIRs. "Hence the equality of commodity price obtained through trade will not, in general, guarantee an equalization of factor prices in each country" [p. 45]. Minhas did not, however, directly test FPE in his work.

B. Tests of FPE in the 1970s

The negative attitude of trade theorists about the empirical relevance of FPE began to moderate in the 1970s. This moderation stemmed, in part at least, from arguments raised in an empirical study by Krueger [1968] and a theoretical analysis by Samuelson [1971].

Krueger [1968] attempts to determine the sources of *per capita* income differences among countries and draws conclusions about the validity of FPE. She assumes that all countries share the same aggregate production function with underlying identical production functions for each good as in the HOLS model. Using 1959 data, Krueger suggests that more than half of the difference in *per capita* income between the US and many less developed countries (LDCs) can be attributed to differences in endowments of human capital.

Although Krueger does not directly test FPE, her results began to transform the negative attitude towards FPE. Stern [1975, p. 35], for example, writes that FPE "has never been subjected to direct empirical investigation, presumably because it appears so obviously violated by the sizable differences in factor prices that exist among countries." However, he interprets Krueger's results as suggesting "that perhaps we were not as far from factor-price equalization as might have been thought. This is an intriguing suggestion that would be interesting to investigate further." This interpretation represents a shift to the point of encouraging empirical work on FPE.

Samuelson [1971] directed attention from FPE to FPC, as noted by Jones and Neary [1984, p. 24]. Samuelson utilizes the specific factor model, introducing identical homothetic preferences across countries. Samuelson's insight, inspired by Ohlin [1933], has implications for empirical testing. Perhaps the empirical relevance of FPE cannot be judged by comparing static factor returns across countries.

The critical test is whether factor prices converge (diverge) as trade expands (contracts). If such trends are found, forces of FPE must be at work.

Officer [1974] combines FPE with purchasing power parity (PPP) to introduce macro FPE (MFPE), built on the aggregate production function which Hicks [1959] argues would provide validity for FPE as a long run tendency. Officer argues that "many kinds and qualities of factors of production are aggregated into two broad factors, labor and capital" [p. 870]. This departure from conventional FPE stems from the contention that the assumption of identical production functions across countries is too unrealistic. He argues that MFPE is based on reasonable assumptions and suggests that testing MFPE is a proper way to test FPE. He presents a model that boils down to the satisfaction of

$$w / w^* = (a_L^* / a_L)\ (p / p^*),$$

where $*$ denotes a foreign variable, a_L represents labor input per unit of output, and p is the price level. A test across 10 industrial countries over the period 1952-70 yields results predicted by MFPE. Officer concludes MFPE "comes close to fulfillment in the real world, which implies that the equilibrium exchange rates defined by the unit-factor-cost and purchasing-power-parity theories are close to identical? [p. 877]. Balassa [1974] criticizes Officer's approach on the grounds that a conclusion about the absolute version of PPP has to be drawn.

Floystad [1974] tests two related assumptions of FPE: the equality of w and r among different industries within a county, and the technical efficiency of resource allocation. He focuses on 17 manufacturing and construction industries in Norway for 1955, 1961, and 1965. The data display significant differences in w and r across industries. Floystad estimates the marginal products of L and K under technical efficiency and compares them against observed marginal products (MPs). Estimates reveal that for 15 of 17 industries, the difference between the actual and optimal w is less than 10%. The difference between the actual and optimal r is less than 10% for only 9 of the 17 industries. Floystad then rejects the assumption of intersector factor mobility. A test for the equality of w and of r in different industries across the countries in the European Free Trade Area (EFTA) and the European Economic Community (EEC) does not reject the hypothesis "that the structure of wages in the manufacturing industries tend to be the same in the trading countries because of equal prices on the products and that wages are more or less equal to the marginal product of labor in a technically efficient situation" [p. 577]. Floystad's pioneering

paper represents the first attempt to test the empirical validity of FPE.

C. Tests of the Dynamic Implications of FPC

FPE generates testable implications that can be divided into two broad categories: static implications that would hold at any given point in time, and dynamic implications that should tend to hold over time. The implication of FPE that factor returns are independent of factor endowments is a static property. On the other hand, convergence of factor productivity or factor prices over time is a dynamic property.

Kotlikoff, Leamer, and Sachs [KLS, 1981] ushered in empirical work on FPC in the 1980s, showing that the process of FPC has been occurring for some countries. Across the US, West Germany, Japan, and South Korea, manufacturing wages (w) converge over the period 1967-77 and capital-labor ratios ($K/L \equiv k$) converge over the period 1958-75. KLS argue that the convergence in k only partially explains the observed convergence of w. The KLS data show [p. 23]

> that the ratio of the Japanese capital-labor ratio to that of the US increased by almost 160 percent between 1967 and 1975. If one assumed that wages were determined by a linear homogeneous Cobb-Douglas production function with a capital coefficient of .3, this growth in relative capital labor ratios would imply a 48 percent increase in relative wages. However, from 1967 to 1975 Japanese relative wages themselves increased by almost 160 percent. A similar set of numbers holds true for Germany.

The authors report the percentage changes in relative wages in 23 industries over the 1967-77: [p. 27] "The process of international wage equalization appears, for the most part, to have occurred uniformly across industries within the various countries, which suggests a freely mobile internal domestic labor market." Despite wage convergence, KLS argue that the HOLS model cannot account for (among other things) the observed large disparity in w across countries.

They develop a modified model in which it is costly to alter the K input. Marginal revenue products (MRPs) of K would be unequal in the short run. Under this condition, w would be unequal across domestic industries despite identical technologies and the equalization of MRPs of labor across countries. The KLS model generates FPE in its long run steady state. Simulation under myopic expectations suggests rapid international wage convergence would occur. Half of the gap between

the initial domestic w and the long run w closes within 6 years. The remaining gap takes much longer to close.

Tovias [1982] uses data from the EEC over the period 1950-75 to test FPE, arguing that the assumptions which lead to FPE hold reasonably well in the EEC. Tovias reports standard deviations and coefficients of variation of manufacturing wages for several years before and after the formation of the EEC in 1957. Calculations reveal relative convergence until 1968, but divergence afterwards. Tovias claims that results provide overall empirical support for FPE, and raises a question: "By how much did free movement of goods and/or workers contribute to the convergence of labor costs?" [p. 388]

Gremmen [1985] criticizes the method of Tovias for testing FPE and provides a partial answer to the above question. Gremmen constructs the following equation:

$$ln\,(w / w^*) = c + \alpha\, ln\,(b) + \beta\, ln\,(k / k^*)$$

where $*$ denotes a foreign variable, $k \equiv K/L$, and b is the level of bilateral trade. The ratio of bilateral imports to GNP is m, and $b \equiv m + m^*$. Gremmen estimates this equation for the EEC over the period 1959-79 when there are high levels of trade, and for 26 other countries among which there is less trade. According to FPE, α should be negative (if $w > w^*$) and β zero. A larger b would mean a higher level of bilateral trade, which would cause w and w^* to approach each other. The *world* equation, which includes the EEC and the other 26 countries, is estimated for 1976. Estimates of parameters support FPE. The elasticity α is about the same (–0.07) for both the EEC and the *world.*

Mourik [1987] raises questions about Gremmen's work, challenging the basic notion that relative resource endowments should not influence relative factor prices significantly even when trade is *intense.* Mourik objects on theoretical and empirical grounds, noting that the validity of FPE hinges on the convergence of k in individual industries across countries. He reestimates Gremmen's model for the EEC, showing that k is an important determinant of factor price differences and finding high partial correlation coefficients between relative real wages and k. Mourik maintains that the first step in truly testing FPE would be the *estimation of sectoral production functions.*

Dollar and Wolff [DW, 1988] note that forces behind FPE should cause industrial labor productivity to converge across countries. They report coefficients of variation of value added per work hour (average productivity) across 28 industries in 13

industrial countries for 1963, 1979, and 1982. A convergence of average productivities (*AP*s) occurs for all industries over the sample period. Moreover, DW show that variation in the employment mix among countries does not play an important role in explaining cross-country differences in aggregate productivity in all manufacturing, nor have changes in employment mixes been an important source of convergence" [p. 550]. DW speculate that the sources of convergence of *AP*s have been convergence of both production techniques and of technology, although no evidence of such convergencies is presented. They find that in 1982 different countries held productivity leads in different industries, which is more compatible with trade theories based on differences in technology.

Mokhtari and Rassekh [MR, 1989] select 16 OECD countries over the period 1961-84 to test the proposition that international trade influences factor prices. MR show that during the sample period trade significantly increased, while both w and k converged. The increase in trade and convergence of k both contribute to explaining convergence in w. MR argue that a measure of trade openness should be included among the variables explaining w, and find it significant in most cases. A classification of *high wage* and *low wage* countries is suggested. Specifically, regression results indicate that Canada, the US, Denmark, Germany, the Netherlands, and Sweden are high wage countries, while, Japan, New Zealand, Austria, Belgium, Finland, France, Ireland, Norway, Switzerland, and the UK are low wage countries.

Mokhtari [1992], using the MR data, shows that the dispersion in manufacturing wages across the sample countries responds asymmetrically to the expansion of imports/output (m/y) and exports/output (x/y) in the short run. An increase in m/y leads to international divergence of w whereas an expansion in x/y induces a convergence. In the long run, however, an increase in both measures of trade openness leads to wage convergence.

Williamson [1992] calculates real wages of unskilled urban workers for 15 countries since 1830. His sample includes Australia, Argentina, Canada, and the US (the New World) and 11 countries in Western Europe (the Old World). The data reveal that real wages diverge across France, Ireland, the Netherlands, Sweden, the UK and the US, the countries for which data are available over the period 1830-56. A process of convergence then sets in, becoming more dramatic around 1870 and lasting through 1988. The interwar period upsets the convergence process, but it resumes in mid-1960s. Williamson suggests that the observed convergence could

be due to factor movements, trade, and technology transfer.

In a subsequent work, O'Rourke and Williamson [OW, 1992] show that the integration of international commodity markets over the period 1870-1913 contributed to factor price convergence between the UK and the US. OW attribute about half of the observed convergence of the wage-rental ratio (w/r) to the convergence of commodity prices. They test FPE directly by linking factor prices to commodity prices rather than to increased trade, as in several of the papers reviewed above. Moreover, OW substantiate Ohlin's contention that equalization of commodity prices between the US and Europe had led to FPE during the last half of the nineteenth century.

Rassekh [1993] finds that FPE is capable of explaining cross-country variation in industry-level wages for a sample of 11 industries in 14 OECD countries over the period 1970-85. He suggests that diffusion of technology, relative dispersion of production techniques, and to a lesser extent international trade at the industry level explain the dispersion of wages across countries. Moreover, examination of wages and production techniques in 7 industries of the nontraded goods sector indicates that variation in these variables across countries in much less than the variation in the traded goods sector.

D. Tests of the Static Implications of FPE

Kotlikoff and Leamer [KL, 1987] introduce and compare three models of international trade. First, the HOLS model creates FPE and by implication equalization of the growth rates of factor prices. The second model assumes complete specialization in an uneven model with more goods than factors. The third model is a specific factor (SF) model with capital immobile between sectors in the short run. In the HOLS model, the accumulation of capital (K) would result in the production of more K-intensive goods with no change in the capital-labor ratio k in any industry. Thus, the marginal product of labor and the wage w would also remain unchanged. Human capital, however, is capable of raising the average w. In the uneven model, more K would increase w and change the pattern of specialization.

The HOLS model implies a zero correlation coefficient "between each country's capital per worker and its industry-specific capital per man, value added per man, and earnings per man" [p. 248]. KL report these coefficients for 28 industries in 28 countries for 1978. Of the 84 correlation coefficients, 75 exceed 0.5 and 33 exceed

0.8, casting some doubt on the HOLS model. Although KL find some support for PFE in regression analysis, the evidence against FPE in taken to be overwhelming. They claim that the other two models receive stronger empirical support. Two observations are offered: "each of the three models plays an important role in determining trade, growth, and factor returns" [P. 269]; and a model with more goods than factors and adjustment costs is superior to any of the three proposed models [p. 230].

Dollar, Wolff, and Baumol [DWB, 1988] present evidence against the static implications of FPE. DWB choose 28 industries in 13 industrial countries in 1980, and find that labor productivity (value added per employee) in each industry varies considerably across countries. DWB note that "for the average industry the cross country productivity differential is of the order of 100%" [p. 31]. Data reveal that "a country that has relatively high productivity in one industry tends to have high productivity in all industries" [p. 33]. FPE implies that countries employing a higher k in the aggregate must be producing relatively more capital intensive goods, rather than using more capital per worker in each industry. To test this implication, DWB calculate the coefficient of correlation between k in all manufacturing and in each industry. Most of the correlation coefficients exceed 0.5 and are significantly greater than zero, rejecting this implication of the FPE model.

Estimation of a translog production function with variable returns to scale leads DWB to suggest that "the economies of scale hypothesis does help considerably in accounting for the observed deviations from the predictions of the FPE, but it still leaves much to be explained" [p. 37]. Tests suggest that the model based on constant returns to scale and productivity differences (across countries at the industry level) outperforms "the model with identical technology and economies of scale" [p. 40]. DWB find that larger economies tend to have higher productivity, which could be the "result of external economies of scale operating at the national level" [p. 43].

While almost all of the empirical work on FPE uses manufacturing wages or industrial labor productivity, Alston and Johnson [AJ, 1988] focus on farmland markets. Their sample countries include Argentina, Australia, Canada, New Zealand, and the US over the period 1960-81. AJ argue that since land is a heterogeneous factor of production, a comparison of growth rates in land prices rather than price levels is appropriate. Empirical results show that "among the five countries the annual growth rates of land prices (pooled across land types) were approximately

equal between 1961 and 1980 and between 1970 and 1980" [p. 151]. AJ also test FPE for the States in the US. Among five cornbelt States, land prices were not at all equal but their growth rates were similar. Similar relationships are detected for land rents. Moreover, the annual nominal exponential growth rates of land prices for 3/4 of the 48 continental States fall within a 95% confidence interval, providing strong support for the implication that trade equalizes the return to similar immobile factors across trading regions (States in this model).

Peterson [1989] estimates marginal rates of return of capital for high, middle, and low income countries, employing a Cobb-Douglas production function. Rates of return are 15%, 24%, and 21% for the three groups respectively. Peterson argues that in the presence of full and accurate information and in the absence of distortions, the rates of return would be equal. No conclusion regarding FPE is drawn, but Peterson's work could serve as part of the basis of a more complete test of FPE.

Elmslie and Milberg [EM, 1992] use a method developed by Brecher and Choudhri [1988] to test the assumption of identical production functions, one of the building blocks of FPE. EM also test a proposition of Kemp and Shimomura [1988] that technological differences in autarchy will quickly dissipate with trade. Tests are conducted by calculating the coefficient of variation of a technology matrix across countries over time. Elements of the technology matrix measure "the total use of factor *i* in the production of all commodities produced in the United States" [p. 9]. EM report the coefficient of variation for 14 sectors in Germany, Italy, Japan, Norway, and Portugal for 1959, 1965, 1970, and 1975, and observe that "as trade openness increased, technologies neither diverged nor dramatically converged" [p. 11]. Accordingly, EM conclude that the assumption of identical production functions is not warranted. EM formulate an alternative model in which technological differences drive trade flows, but do not test their model. Since EM test only 5 countries, it is difficult to accept their finding as a severe blow to the FPE model. Their results cannot, however, be dismissed because FPE itself has received mixed empirical reviews.

It should be mentioned that a convergence of technologies across countries is expected as international trade expands. The reason is that increases in trade will enhance competition, forcing firms to employ more advanced technology. Such a process should lead to the convergence of technologies across countries. The literature on the convergence of *per capita* GDP revolves around the diffusion of technology from the more advanced to the less advanced economies. For seminal

papers on the convergence of *per capita* GDP, see Baumol [1986], Abramowitz [1986], and Dowrick and Nguyen [1989]. For the role of international trade in the convergence process, see Barro and Sala-i-Martin [1990], Ben-David [1991], and Rassekh [1992].

IV. Policy Implications of FPE

Trade theories generally suggest that international trade is mutually beneficial, although the gains from trade may not be evenly distributed. FPE implies that workers (at least in some skill groups) in high wage countries may lose from trading with low wage countries. This is a crucial issue for potential free trade areas with a wide range of wages across members.

Leamer [1992b] documents the convergence of industrial wages among developed countries during the period 1960-89, showing that until 1978 wage convergence was mainly due to "extraordinary real wage growth in Japan, West Germany, France and Korea but relatively less wage growth in the United States" [p. 7]. From 1978 to 1989, wages in the US and Germany declined while wages in Japan continued to rise, surpassing wages in the US. Moreover, Leamer presents evidence of wage convergence among countries in the EEC and the EFTA. Between 1978 and 1989, real wages of the high wage countries (Denmark, Germany, Belgium, the Netherlands) fell while real wages of the low wage countries (Ireland, Spain, Greece, Portugal) generally rose [p. 8]. Although Leamer supports free trade, he warns that ". . . in the absence of very substantial increases in trade barriers, real wages in the U.S. are virtually certain to decline over the next decade because of the forces of wage equalization" [p. 9]. However, this pattern of wage movements is not necessarily evidence supporting FPE because the figures are average industrial wages which do not reflect shifting skill levels. Moreover, no econometric effort is made to attribute wage movements to the forces underlying FPE. Nevertheless, the evidence and arguments are compelling enough to cast doubt over the political popularity of free trade in the high wage countries.

Can the HOLS paradigm provide policy guidelines? An implication of the Stolper-Samuelson theorem is that the move toward free trade would make a country's relatively scarce factors (unskilled and low-skilled workers in the US) worse off and the relatively abundant factors (skilled workers and capital in the US) better off. Maintaining protection or abandoning free trade to protect low wage

workers is an inefficient economic alternative. A more sensible but politically difficult policy would be to redistribute some of the gains from free trade to the losers. McCurdy and Mroz [1991] present evidence that the income of college educated labor in the US increased by 8% while the income of workers with less education declined between 1978 and 1989. While other forces may be at work, the falling wages of unskilled and low skilled workers in the US may be due to increased free trade. If the HOLS model is a guide for policy, the abundant factors which gain from free trade could compensate the scarce factors for their losses.

FPE has deep implications for the less developed countries (LDCs). Hirschman [1977] refers to the publication of Samuelson's FPE papers [1948, 1949] as "one of the important, though hardly ever mentioned, dates in the emergence of development economics" [p. 67]. Hirschman argues that the significance of FPE to economic development goes far beyond the general proposition that international trade is mutually beneficial, because "Samuelson's results . . . pointed to trade as a potential force toward the equalization of incomes around the world" [p. 68].

Whereas FPE might sensibly make some workers in the developed countries (DCs) uneasy about trading with the LDCs, it should entice LDCs to want free trade with the DCs. Development economists, however, have generally taken the opposite position in advising the LDCs. Streeten [1979] notes that leading development economists have expressed disbelief in the ability of FPE to bring about international wage equality: "Raul Prebisch, Hans Singer and Gunnar Myradal, less elegantly but more realistically, challenged not only Samuelson's findings but the more general view that equilibrating forces showed a tendency for the fruits of economic progress to be widely and, after time-lag, evenly shared" [p. 58].

There have been, of course, other attempts to cast doubt on FPE as a beneficial paradigm for LDCs. For example, Moore [1990] argues that a 3×3 model is more appropriate than the 2×2 model for the analysis of trade policy in Central America, where economies can be described by a model with manufacturing, agricultural exports, and traditional subsistence agriculture. In Moore's model, trade liberalization would reduce the return to labor that constitutes up to 60% of the population in some parts of Central America. He suggests that a land redistribution program could make trade liberalization beneficial to the poor in that region.

For the LDCs, a belief in FPE amounts to a belief in the benefits from free trade. Economists who believe in the overall efficiency of the market system regard FPE as a beneficial force for the LDCs. Krueger [1990] points out that LDCs which have

resorted to protectionist trade regimes in the postwar era have been disillusioned by results and most have changed their policies. It is unrealistic, however, to expect LDCs to continue a move to free trade as long as their trade partners in the DCs protect the relatively high wages of their unskilled workers.

V. Suggestion for Further Research

Where do we stand on the scientific status of FPE? This review of the literature suggests that systematic testing of FPE has only just begun. If FPE is granted the status of a null hypothesis, it has not been conclusively rejected. Potential avenues for further research discussed below.

Empirical tests of FPE have been confined to DCs. Effort should be made to include the newly industrialized countries (NICs) and the LDCs. Kotlikoff and Leamer [1987, p. 229] suggest that large differences in factor returns could be due to sufficiently dissimilar endowments which place countries in different cones of diversification. FPE would then have to be tested separately for DCs, LDCs, and NICs within particularly same endowment cone. Convergence of factor prices within groups but not necessarily between groups would be expected. Care should be taken to ensure that only instances of increasing trade in similar products is included.

Factors need to be disaggregated to the greatest extent possible. A change in relative manufacturing wages would provide evidence regarding FPE only if manufacturing in each country were made up of similar industries with similar production techniques. Trade theorists have long recognized the need to include skilled labor as a separate input. Labor skill groups are not readily separable, and should be treated as separate inputs. Capital also comes in varieties: machinery, equipment, and buildings, some of which are sector specific. Land is hardly a homogeneous input. Leamer [1984] sets a minimum standard for the classification of productive inputs. Dollar and Wolff [1988] and Kotlikoff and Leamer [1987] come close to catching the spirit of FPE in the application of high dimensional models.

The role of different forces in the convergence of labor productivity uncovered by Dollar and Wolff [1988] deserves study. Both production techniques (capital-labor ratios) and technologies (production functions) may converge across countries in each industry. Mokhtari and Rassekh [1989] find that expansion in interna-

tional trade and convergence of capital-labor ratios across countries are associated with convergence of manufacturing wages. The evolution of capital-labor ratios in individual industries and countries needs to be carefully examined in relation to the evolution of factor prices. In this regard, Rassekh [1993] provides some preliminary results.

Using exchange rates to convert income or wages to a common currency may overstate the difference in purchasing power across countries. In testing FPE, wages have to be adjusted for purchasing power to yield a reliable comparison. Tovias [1982, p. 381] argues that "foreign exchange rates of conversion seem to be sufficient in particular because we are looking into long-term trends." This would be correct if inflation rates in the sample countries converge in the long run and short run or spot exchange rates were not *out of line*. Prices of nontraded goods may also be critical in calculating differences in real wages across countries.

Production functions in various industries in different countries need to be reliably estimated. Although it is not necessary to estimate production functions to test the implications of FPE, knowledge of underlying production functions would flesh out skeletal factor proportions theory. The vast literature on applied production analysis provides a footing on which international economists can build more complete tests and applications of factor proportions theory.

It can be anticipated that estimated production functions will be somewhat different across countries. FPE could nevertheless be stated as an approximate theorem: If production functions are similar across nations and other sufficient conditions hold, factor prices will become approximately equal with trade. Observed international differences in production functions would be insufficient reason to completely abandon factor proportions theory, the spirit of the FPE theorem, or the generic belief in FPC.

There is an informal view of an economy which underlies the FPC argument. Algebraic general equilibrium models formalize this picture, but may cause trade theorists to lose sight of the basic issues. Models of imperfect competition provide detail about the strategic workings of particular industries, but fail to provide broad insight. FPE remains a focal point of research in international economics.

VI. Conclusion

This paper surveys the theoretical evolution and empirical investigation of the

factor price equalization theorem since its inception early this century. Theoretical advancements point to the richness of FPE as a conceptual framework. Empirical investigations provide tangibility for the proposition by dispelling some of the abstraction that surrounds FPE.

Leamer [1992a] presents a powerful argument against *testing* trade models. Rather than attempting to accept or reject a model, Leamer suggests that the focus of empirical work should be on identifying "circumstances in which the model is useful and other circumstances in which it is misleading" [p. 2]. The reviewed empirical works on FPE can be seen as following Leamer's insight. While much remains to be done, the profession is realizing that empirical investigation is critical for the science to progress.

Valuable ideas and worthy propositions tend to survive in scholarly circles. FPE has continued to attract fresh minds despite its dismissal on *a priori* grounds as an unrealistic proposition by a portion of the profession. This survey is meant to moderate the view of the skeptics and encourage scientific progress on FPE.

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