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TECHNOLOGY, TRADE, AND FACTOR PRICES

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ABSTRACT

A number of recent studies appear to show that international trade is a secondary factor in the growing inequality of wages, with technology probably the main culprit. These studies have, however, been subjected to severe and in some cases harshly worded criticism by trade theorists, who argue that the authors of these studies have misspecified the impacts of both technology and trade on factor prices. This paper shows that it is the critics who are confused. In particular, much recent discussion about technology, trade, and wages is marked by a failure to distinguish between the models we all use and the particular thought experiments we typically use to teach these models -- which happen not to be the appropriate thought experiments we need to analyze the real-world issues.

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Over the last decade or so, the Stolper-Samuelson theorem -- that classic piece of trade theory which asserts that changes in goods prices have magnified effects on factor prices -- has moved from midterm exams into the heart of real-world debates over economic policy. The reason is that an expansion of world trade, and especially of manufactures exports from low-wage countries, has coincided with a fall in the real wages of less-skilled American workers (and with rising unemployment in other advanced countries). It is natural to suspect a link between trade and declining wages; indeed, many commentators, including some economists, have not hesitated to assert flatly that growing trade is the principal cause of wage decline.

It is probably fair to say, however, that the majority view among serious economic analysts is that international trade has had only a limited impact on wages. Skepticism about the effects of trade on wages rests essentially on the observation that despite its growth, trade is still quite small compared with the economies of advanced nations. In particular, imports of manufactured goods from developing countries are still only about 2 percent of the combined GDP of the OECD. The conventional wisdom is that trade flows of this limited magnitude cannot explain the very large changes in relative factor prices that have occurred -- in particular, the roughly 30 percent rise in the wage premium associated with a college education that has taken place in the United States since the

1970s. Low estimates of the impact of trade on wages are often, though not always, based on a methodology that tries to compute the "factor content" of trade, and divides the trade-induced changes in relative "effective" factor supplies by some estimated or assumed elasticity of substitution.

If trade does not explain the bulk of the change in factor prices, what does? The conventional answer is that technology is the culprit; in particular, that there has been a pervasive skill-using bias in recent technological change, which has shifted demand toward skilled and away from unskilled labor.

But while the view that recent changes in the distribution of income primarily reflect technology rather than trade may be the majority opinion, it has been harshly criticized by some trade economists -- especially by Leamer (1994, 1995), who describes the work purporting to show limited impacts of trade as "incompetent, immaterial, and irrelevant". The critique by Leamer and others may be summarized as follows:

1. The observation that the volume of trade between low-wage and high-wage countries is small is irrelevant: prices rather than quantities are what matter, and prices are determined on the margin.

2. The attempt to estimate the impact of trade by looking at its factor content is a nonsensical exercise, betraying a failure to understand basic trade theory.

3. The factor bias of technological change is also irrelevant: trade theory tells us that what matters is the sector in which technical progress occurs, not the factor bias of that change.

If correct, this would be a damning critique -- and some of the critics have, as already indicated, not hesitated to use strong language in pressing their case. *But the critique is simply wrong.* Trade volumes are *not* irrelevant: if one poses the question correctly, one immediately realizes that small trade volumes are inconsistent with a story that attributes large distributional effects to trade. The factor bias of technological change is *not* immaterial, except in the case where such change takes place in a small open economy (as opposed to one that can affect world prices), *and* where technical change occurs only in that economy (rather than occurring simultaneously in other economies as well); since the real situation does not meet either criterion, factor bias definitely does matter. Most surprisingly, the much maligned use of a factor content approach to infer the effects of trade on factor prices is not "incompetent"; it turns out to be an entirely justified procedure when trade is a small share of GDP, as it is for the OECD as a whole.

It is puzzling that highly respected economists, in challenging the view that technology rather than trade has been the main cause of recent changes in factor prices, have misunderstood fairly simple conceptual issues; it is positively dismaying that some

of them, even while misinterpreting the implications of standard trade models, have adopted the pose of guardians of the true tradition, defending theoretical purity against the barbarians. Let us, however, postpone the question of what went wrong to the end of this paper, and deal with the substantive analysis.

This paper is in six parts. It begins with the impact of technology on factor prices. Part 1 reviews the standard analysis of technology and factor prices in a one-good economy, while part 2 turns to a multiple-good economy, discussing the relative roles of sector and factor bias of technological change. Part 3 offers a discussion of the relevance of trade volumes to the assessment of trade's impact on factor prices. Part 4 develops some algebra for the relationship between factor prices and factor supplies. Part 5 then uses this machinery to show the validity of the factor content approach when assessing the impacts of small trade shares on income distribution. Finally, Part 6 reviews the debate and asks how it can have gotten so far off track.

1. Technology and factor prices in a one-good economy

A useful starting point for any discussion of the impact of technology on factor prices is the analysis first introduced by Hicks (1932), which showed how the effects of technical progress in a one-good economy depend on its factor bias.

Consider a constant returns, competitive economy that

produces a single aggregate output using two inputs, skilled labor (S) and unskilled labor (U).[1] In Figure 1 the curve II is the initial unit isoquant. The slope of the ray OE is the aggregate ratio of unskilled to skilled labor in the economy, and the slope of *ww* is the ratio of skilled to unskilled wages.

Now consider the effects of technical progress, which can be represented as an inward shift of II, say to I'I'. If the relative supplies of skilled and unskilled labor remain unchanged, the new relative wage rate will be determined by the slope of I'I' where it crosses OE.

Clearly, the effect of technological change on factor prices depends on the *bias* of that change. If technical progress is Hicks-neutral, that is, if the unit isoquant simply shifts radially inward, there will be no change in relative factor prices. If technical progress is skill-biased, that is, if the ratio of skilled to unskilled employment will rise at any given wage ratio, then the effect of this technical progress will, as shown in Figure 1, be to raise the skill premium to a level indicated by the slope of *w'w'*.

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Throughout this paper I will think in terms of a two-factor economy in which the two factors are skilled and unskilled labor. Why not capital and labor? Because the empirical fact is that while the skill premium has risen sharply, the share of compensation in national income has been quite stable. Ideally we would work with three or more factors, but to do so would obscure the important issues treated later in the paper.

Notice that it is quite possible that technical progress will actually lower the real wages of some workers. The intercept of $w'w'$ with the vertical axis measures the amount of unskilled labor necessary to purchase one unit of output -- i.e., the inverse of the real wage of unskilled labor. As drawn in Figure 1, this real wage has clearly declined.

This is all standard theory, more than 60 years old. What makes it relevant is that there is overwhelming evidence that recent technological change has indeed been strongly skill-biased. The essential point was made clearly by Lawrence and Slaughter (1993): although the wage premium associated with education has risen sharply since the 1970s, which should other things equal have led to a substitution away from skilled labor, in fact there has been a rise in the college-educated share of employment -- not only in the economy as a whole, but within almost every industry.

Does skill-biased technological change, then, explain the rise in the relative wage of skilled workers? I will turn to critiques of this idea in the next section, and to the claim that trade rather than technology is the culprit later in the paper. Before getting to these questions, however, it may be worth mentioning one potentially worrisome issue that arises even if one is willing, for the sake of argument, to think of the economy as if it produced only one good. The issue is the following: has the growth in total factor productivity been sufficient to be consistent with the large changes

we have actually seen in factor prices? [2]

To see why this might be a problem, consider Figure 2. Here II represents an estimate of the unit isoquant at some initial date -- say 1973 -- and E shows the unit inputs of skilled and unskilled labor at that date. At some later date, say 1989, we observe the unit inputs described by E', and the factor prices indicated by $w'w'$. The situation shown here is one in which the growth in average labor productivity has not been very large, indeed in which the input of skilled labor per unit of output has actually increased; but factor prices have changed substantially. Is this outcome consistent with a technological explanation?

The answer is no. One thing we know about technical progress is that old technologies remain available; geometrically, that means that the new unit isoquant cannot lie outside the old one at any point, and therefore also that any factor price line tangent to that new unit isoquant cannot cross the old isoquant. This criterion is clearly violated in Figure 2. In fact, in this case output would literally be cheaper to produce at 1989 factor prices using the 1973 input coefficients. If the real data looked like this, we would

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[2] This concern was suggested to me by Kenneth Arrow. It should not be confused with the argument sometimes made that technological change cannot explain wage changes because the rate of growth of total factor productivity has not accelerated. This argument involves a crude confusion between the rate of TFP growth and the bias of that growth.

therefore be entitled to conclude that technology is not a sufficient explanation for the change in factor prices. (Even if it is not literally cheaper to produce using the old input coefficients, we would still reject the technological explanation if the new factor price line crossed an estimate of the old unit isoquant based on a reasonable elasticity of substitution).

We see, then, that a technological explanation of changes in factor prices is not a tautology: even before we get to issues posed by international trade, we must face the possibility that a technology explanation will be internally inconsistent. This is most likely to happen if there are large factor price changes over a period of small improvements in productivity -- which sounds qualitatively like a good description of the last 20 years in the United States. Before we proceed, then, we had better make sure that the data do not reject a technological explanation out of hand.

Figure 3 shows some relevant data for the United States, based on wage data from Mishel and Bernstein (1994) and on productivity data from the *Economic Report of the President*. Skilled workers are identified with college-educated workers; unskilled workers with all others. The 1973 isoquant is an estimate of the unit isoquant based on an elasticity of substitution of 1. It turns out that the technological explanation passes this test: although US productivity growth has been disappointing, it has been large enough that even with a reasonably large elasticity of

substitution the data are consistent with a factor-bias explanation of changing factor prices. While this by no means demonstrates that a technology story is correct, it does show that it is feasible.

But there are some trade economists who assert that the whole issue of factor bias in technology is irrelevant -- that while factor bias may matter in a one-sector model, when we consider trading economies with multiple sectors it ceases to have any impact on factor prices. To assess this claim, we must now extend the model.

2. Technology and factor prices in multi-good models

To understand the objections of Leamer and others to analyses that stress the factor bias of technological change, let us now consider an economy that uses skilled and unskilled labor to produce *two* goods, a skill-intensive good X and an (unskilled) labor-intensive good Y. Let us also follow Leamer (1994) and initially assume that relative goods prices may be taken as given. We will see shortly that this is a very misleading assumption, but it is important to see Leamer's logic.

Figure 4 uses a Lerner diagram to represent the equilibrium of this economy. The two curves XX and YY are not unit isoquants: they are "equal value" isoquants, each corresponding to the same *value* at world prices as the other. (Thus each might represent $1 million worth of its respective good).

If the country is to produce both goods, factor prices must be such that $1 million of X and $1 million of Y cost the same amount to produce. Thus the relative wage must equal the slope of the line *ww* that is tangent to both isoquants. And we can then check to confirm that the country will actually produce both goods: it will do so if and only if its endowment lies within the "cone of diversification" defined by the broken lines in the figure.

Now consider the effects of technological progress. Suppose that there is an improvement in the total factor productivity of the X sector, but that *there is no change in the relative price of X* -- which turns out to be the key assumption. Then the relevant isoquant will shift in, say to X'X', and the relative wage of skilled labor will rise.

What is immediately apparent is that any improvement in the technology for producing X will raise the relative wage of skilled labor -- regardless of the factor bias of that change. And similarly any technological advance in Y will shift factor prices the other way. The model thus seems to imply that the emphasis on factor bias suggested by the one-good model is all wrong when we are considering multi-good, trading economies: it is the sector of change, not the factor bias, which matters. And this is precisely the conclusion that Leamer draws.

But is this really right? Does adding a sector and the possibility of international trade really make such a dramatic

difference? No -- not if we think carefully about what thought experiment we ought to be performing.

Notice that the exercise shown in Figure 4 is actually a rather peculiar one. It envisages technological progress that occurs in an economy that faces fixed goods prices. To make sense of this scenario, we must suppose not only that this is an open economy that is sufficiently small that it cannot affect its terms of trade, but also that the technological advance is *unilateral* - that the same technological change is not also happening elsewhere. Examining this scenario is a useful and indeed canonical classroom exercise, but it is not at all what people who attribute recent changes in factor prices to technology have in mind. Rather, what they have in mind is a change in technology that is occuring simultaneously in the United States, Western Europe, and perhaps elsewhere -- that is, in economies that are individually far from being price-takers on world markets, and that collectively may even be thought of as constituting an "almost closed" economy.

Is this a minor correction, or might it make a big difference to our results? Well, consider for a moment the impact, not of technological change, but of factor supplies on factor prices. It is a familiar point that as long as a small open economy's endowment remains within the "cone of diversification", changes in factor supplies have no effect on factor prices: the economy is able to accommodate the changes in factor supplies via a reshuffling of

production, so that the demand for factors is in effect infinitely elastic. But few economists would claim that factor prices in the United States, let alone the OECD as a whole, are really unaffected by factor supplies. That is, we all believe that because goods prices are endogenous, an increase in the supply of skilled labor will reduce its wage rate; and we would all regard as unsatisfactory any model in which this was not the case.

But the irrelevance of factor supplies and the irrelevance of the factor bias of technical change in a small open economy are simply two sides of the same coin. That is, neither changes in factor supplies nor the changes in factor demands that result from biased technical change can affect factor prices in a model in which the elasticity of factor demand is infinite. And conversely, if you find the implications of such a model for the effects of factor supplies on factor prices unacceptable, you must also reject the implications of that model for the effects of the factor bias of technological change.[3]

Suppose that we believe that the right thought experiment is not to consider a unilateral technological change in a small

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[3] Leamer (1995) appears to disagree with this point. He asserts as a basic principle that the effect of technological change on factor prices depends on the sector, not the factor bias, of that change -- but concedes that it is a defect of his model that factor supplies have no effect on factor prices.

economy, but rather a simultaneous technological change in the world as a whole -- that is, in effect technological change in a *closed* economy. How does this affect our conclusions about which aspects of technological change matter for factor prices?

It is useful to consider a particular example which makes clearly the point that endogenizing prices can thoroughly alter the results of small-economy models. Consider, then, a model of a two-sector closed economy with two special features. First, demand is Cobb-Douglas: a constant share α of income is spent on the skill-intensive good X. Second, there are fixed proportions in each sector.

The assumption of fixed proportions means that we can determine the allocation of resources between X and Y without reference to factor or goods prices. The allocation of resources is illustrated in Figure 5. Resources devoted to X are measured from the origin O_X, resources devoted to Y from the origin O_Y. The factor ratios in X and in Y production are shown by the slopes of O_XX and O_YY respectively; and the economy's allocation of resources is therefore shown by the point Q.

Given this allocation, we can then determine factor prices. Let w be the wage of skilled relative to unskilled labor; let S and U be the economy's supplies of the two factors; and let S_X, U_X be the skilled and unskilled labor employed in the X sector. Since all income is factor income, and since a share α of that income is spent

on X, we have

$$wS_X + U_X = \alpha(wS + U) \qquad (1)$$

or, rearranging,

$$w = \frac{\alpha U - U_X}{S_X - \alpha S} \qquad (2)$$

Now consider the effects of technical change. First, consider the effect of Hicks-netural technical change in either sector -- that is, technical change that does not affect the factor ratio in the progressing sector. It is immediately clear from Figure 5 that such change has no effect on the allocation of resources -- and it is therefore clear from (2) that it has no effect on factor prices. In other words, the conclusion from the small-economy model that Hicks-neutral technical progress in the skill-intensive sector necessarily raises the return to skill turns out to be untrue.

On the other hand, consider the effect of a factor-biased technical change. In Figure 5 I show the effects of skill-biased progress in the labor-intensive sector Y. (Recall that in the small-economy model technical progress in Y must lower w, regardless of its factor bias). The S/U ratio shifts upward to the slope of $O_Y Y'$.

The allocation of resources shifts from Q to Q': both S_X and U_X decline. Referring back to (2), we see that this implies that *w* rises. It is easy to show that the same is true if skill-biased change occurs in the X sector. That is, skill-biased technical change in either sector raises the return to skill.

In sum, in this example the dictum that it is the sector, not the factor bias, of technical change that matters is precisely wrong. Neutral technological change in either sector has no effect on relative factor prices; biased technological change in either sector raises the price of the factor toward which it is biased. Or to put it differently: in this case a two-sector model behaves just like the one-sector model described in the previous section.

This example relied for clarity on the special assumptions of Cobb-Douglas demand and fixed proportions. Are these assumptions crucial to the results?

Consider first relaxing the fixed proportions assumption. It is straightforward to confirm that the proposition that Hicks-neutral technical progress does not affect *w* remains true. After all, (2) continues to hold; so if technological change does not alter the allocation of resources, *w* will not change. But if technological change has no factor bias, and *w* does not change, then the allocation of resources will not change either! It is also possible to show that even with flexible factor proportions skill-biased technological change will raise *w*. So the fixed-proportions

assumption is not crucial.

What about relaxing the assumption of Cobb-Douglas demand? Suppose that we continue to assume homothetic preferences, but now allow the elasticity of substitution to differ from 1. Then the share of expenditure falling on X, α, now becomes a function of the relative price of X, $\alpha(p)$. This function will be decreasing or increasing in p depending on whether the elasticity of substitution is greater or less than one.

Now suppose that we consider Hicks-neutral technological progress in the X sector. This will lead to a fall in p. [4] By inspection of (2), we then see that if the elasticity of substitution in demand is greater than one, technical progress in X will indeed raise the skill premium. (The small open economy case may be thought of as the extreme version in which the elasticity of substitution becomes infinite). But if the elasticity of substitution is less than one, even Hicks-neutral technical progress in the skill-intensive sector will actually reduce the skill premium.

Is this an extreme or perverse possibility? Not necessarily. These are highly aggregated sectors of the economy, and it is quite possible that the elasticities of substitution in consumption among broad expenditure classes are less than one. (For example, the

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[4] Of course, we should think of p and w as being simultaneously determined. It is straightforward but tedious to work this out; the results are unchanged.

secular downward trend in the manufacturing share of employment and value-added is commonly attributed to the fact that manufacturing productivity has risen faster than service productivity; this amounts to an assertion that the elasticity of substitution between manufacturing and services is considerably less than one).

Those trade economists who have asserted that factor price trends depend only on the sector of technical change, and not at all on the factor bias of that change, have therefore got it almost exactly the wrong way around. When technological change occurs in a large economy, or occurs simultaneously in a number of economies which are collectively able to affect world prices, skill-biased progress does indeed tend to raise the skill premium. Meanwhile, the sectoral bias of technical change has an effect which is ambiguous if it is there at all.

In particular, an exercise like that of Leamer (1994), in which he attempts to estimate the effects of technological change on factor prices based on the assumption of given goods prices, is doubly misleading. It neglects the effects of factor bias, which might well be the main story; and even if technological change had been purely Hicks-neutral (which we know it has not), these estimates could easily get not only the magnitude but even the sign of the effects of that change on factor prices wrong. Such estimates tell us nothing at all about the actual role of technological change in

growing wage inequality.

The reason that Leamer attempted a direct estimate of the effects of technological change on factor prices was, of course, his rejection of previous attempts to estimate the technological effect indirectly, by first estimating the effect of international trade on factor prices -- a procedure that typically finds only small effects of trade, and thus ends up assigning most of the weight to technology as a residual. At least some other well-respected trade economists have shared his view that conventional estimates of the impact of trade on wages, estimates that depend crucially on calculations involving the volume of trade, are conceptually flawed. But are they? In the remainder of this paper I turn to the question of what, if anything, we can learn from calculations that depend on the volume and/or factor content of trade.

3. Goods prices, factor prices, and the volume of trade

This paper is intended as a discussion of methodology, and will not attempt a fresh empirical analysis of trade and wages. Nonetheless, it is important at this point to indicate the orders of magnitude of the changes that have occcurred, since these are central to the argument.

Since 1970 there has been a dramatic widening of wage differentials in the United States. For example, real wages of workers at the 90th percentile have risen about 15 percent, while

those of workers at the 10th percentile have fallen about 25 percent. The widening of wage differentials has been less dramatic in other advanced countries, but there has been a secular rise in unemployment in Europe that is widely regarded as the result of an attempt to suppress pressures for growing inequality.

Over the same period international trade, especially the exports of manufactures from low-wage countries, has increased substantially. In particular, OECD imports of manufactures from newly industrializing economies were negligible in 1970, but are about 2 percent of the combined GDPs of the OECD countries today.

Does the growth of North-South trade explain the rise in wage inequality in the advanced countries? The theoretical possibility that it might is obvious: if imports of labor-intensive products have led to a fall in the relative price of these goods in advanced economies, this would imply a Stolper-Samuelson effect that should indeed lower the real wages of less-skilled workers. Most empirical workers have concluded, however, that trade explains at most a fairly small fraction of the rise in inequality; the main reason they reach this conclusion is that although imports of labor-intensive manufactures have grown rapidly, they believe that these imports are still too small as a share of OECD income to

explain the massive increase in wage differentials. [5]

A number of trade economists have, however, rejected the logic on which this assessment is based. They point out that the Stolper-Samuelson theorem demonstrates a relationship between prices of goods and prices of factors -- that the volume of trade does not enter into the theorem's statement. As long as a country faces prices that are determined on world markets, they argue, changes in these world market prices will drive changes in domestic factor prices, regardless of the share of trade in GDP. And thus the fact that North-South trade is still not very large is "immaterial" for the question of how much of the growth in wage differentials is explained by trade.

This argument sounds compelling, and some trade economists have adopted a magisterial tone in rejecting the relevance of trade volumes to any assessment of the impact of trade on wages. But before we accept the proposition that "economic theory tells us that trade volumes don't matter", we need to think carefully about what question we are trying to answer.

What does it mean to say that North-South trade did or did not "cause" the rise in wage inequality? Deardorff and Hakura (1994) have usefully introduced a bit of legal jargon, pointing out

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[5] Studies that have reached this conclusion include Borjas, Freeman, and Katz (1992), Bound and Johnson (1992), Krugman (1995), Lawrence (1995), and Lawrence and Slaughter (1993).

that what we are really asking is a "but-for" question: "What would wages be, *but for* the availability of manufactures imports from low-wage countries?"

More specifically, we may phrase the question in terms of a counterfactual. In 1970, the OECD imported essentially no manufactured goods from developing economies. It is possible to imagine an alternative history in which the OECD countries have acquired the technology and resources of the mid-1990s, but in which trade with the newly industrializing economies remains negligible (either because these countries did not develop, or because protectionist barriers have blocked off the potential trade). How different would wages be in this alternative world? This, surely, is the question we are asking when we ask how much of the decline in low-skill wages was "caused" by trade.

Notice that we can immediately see that looking at the actual movements in goods prices, and the implications of these movements for factor prices, cannot answer this question. The reason is that actual movements in goods prices may reflect developments in the advanced countries *that would have happened even in the absence of North-South trade*. Changes in advanced-country factor supplies and technology -- the latter operating both directly and via induced changes in factor prices -- might well exaggerate, obscure, or reverse the changes in goods prices due to the opening of trade. It might be the case, for example, that

technical progress is more rapid in skill-intensive than in labor-intensive sectors, leading to a fall in the relative price of skill-intensive goods even though trade leaves that relative price higher than it would otherwise have been. Or, conversely, a rise in the relative price of skill-intensive goods might reflect skill-biased technical change which raises the skill premium, rather than the opening of trade with labor-abundant countries.

In other words, the economist trying to analyze the effects of trade on wages is not faced with the textbook problem of predicting the effect of a *given* change in goods prices on factor prices. Instead, the problem is how to infer the impact of trade, as opposed to other influences, on goods prices -- only then can one calculate the implied factor price effect. And once one realizes that the issue is one of inference rather than a question about the mechanics of the model, one also realizes that the volume of trade is not irrelevant or immaterial; it is a crucial piece of evidence.

Experience with trying to explain this point reveals that it is surprisingly difficult to get across, so it may be useful to offer an analogy. (I do not claim that the story is true, though it might be). Suppose that it turns out that over the past decade Japan has become a significant consumer of coffee, due to changing tastes; and that Japanese imports now amount to 2 percent of the world's coffee production. And suppose that it is also the case that world coffee prices have doubled in real terms over the same period. What

would I say to someone who asserted that Japan's coffee imports have caused that rise in world prices?

The answer is surely that I can reject his claim, and assert that only a small fraction of the price rise is due to Japanese imports -- other factors, like bad weather and pests, must be the main explanation. The argument runs as follows: if Japan had not developed a taste for coffee, the rest of the world would no longer be able to have an excess supply of coffee corresponding to Japan's imports; the world price of coffee would therefore have to be sufficiently lower to eliminate that excess supply. But because Japanese imports are still a fairly small share of world output, given reasonable elasticities of supply and demand it would not require a very large fall in prices to eliminate that excess supply -- surely not a 50 percent fall in prices. Indeed, the most natural way to estimate the role of Japanese imports in the change in world prices would be to do precisely the implied exercise: to use estimates of the supply and demand elasticities to calculate the fall in the price that would be necessary to eliminate the rest-of-world excess supply that offsets Japan's excess demand.

Suppose that someone were to object that this is bad economics: the volume of Japanese imports is irrelevant, because coffee prices are determined on the margin. The answer would be that he has misunderstood the nature of the exercise: we are not making an assertion about how markets work, we are trying to use

market data to infer the answer to a "but-for" question. And for this exercise volume data are not only relevant, they are crucial.

This is a hypothetical, partial-equilibrium example, but the same principles apply to the real general-equilibrium issue of the effects of trade on factor prices. Figure 6 illustrates the argument. We envision a simplified world in which an aggregate OECD trades with an aggregate consisting of all newly industrializing countries, exporting skill-intensive X and importing labor-intensive Y. Actual OECD production and consumption are indicated by Q and C respectively; the curve passing through Q and C represents the NIE offer curve. When we ask "What effect has trade had on prices?", we are in effect asking the question, "What would OECD relative prices be *but for* the possibility of trading with the NIEs?". That is, we are asking how much higher the relative price of labor-intensive products would be at the autarky point A.

This question may, at least in principle, be answered by calibrating a computable general equilibrium model of the OECD to the actual data -- *including the volume of trade* -- and calculating the difference between the actual relative price and the relative price consistent with autarky. One can then also calculate the implied difference between actual and autarky factor prices; it is this difference which may be regarded as the effect of trade on factor prices. (Notice that for this exercise it is not necessary to model the internal workings of the newly industrializing economies, or even

the elasticity of their offer curve; in particular, data about their labor force and capital stock do not play any role in the calculation).

A quick-and-dirty version of this exercise was carried out in Krugman (1995). I found that North-South trade has lowered the relative price of labor-intensive products by less than 1 percent, and the relative wage of unskilled workers by less than 3 percent. That is, trade has caused a significant but fairly small fraction of the massive increase in wage inequality in advanced countries. One would not want to take this precise number seriously. We may, however, make one fairly robust assertion: in any model with plausible factor shares and elasticities of substitution the offer curve of the OECD will be fairly flat. Given the small actual volume of trade with newly industrializing countries, this means that the difference between actual and estimated autarky prices will not be very large -- and therefore that the estimated effect of trade on factor prices will not be very large either.

I would argue that this is basically the right way to think about the issue of trade and factor prices. At the very least, this approach lays down a challenge to economists who claim that trade has had very large effects on wages: can they produce a general equilibrium model of the OECD, with plausible factor shares and elasticities of substitution, that is consistent both with their assertions and with the limited actual volume of trade? If they

cannot, they have not made their case.

But many economists studying the impact of trade on wages have been reluctant to commit themselves to a specific CGE model. Instead, they have tried to use a shortcut, by estimating the "factor content" of trade. That is, they add up an estimate of the factors of production used to produce exports, subtract an estimate of the inputs that would have been used to produce imports, and consider the difference to represent changes in "effective" factor supplies. These changes in effective supplies are then treated as if they were changes in actual resources: the percentage change in the ratio of the "effective" supplies of skilled to unskilled labor is divided by an estimate of the elasticity of substitution to estimate the impact of trade on relative wages.

This shortcut has been almost universally rejected by trade theorists -- myself included -- as an invalid procedure. The tone of these rejections has ranged from regret that a plausible-sounding approach cannot be given a good theoretical rationale, to caustic denunciations of economists who calculate the factor content of trade as "incompetent". But have we been right to reject the factor content approach so summarily? To examine this question, we need to make a brief detour into the relationship between factor supplies and factor prices.

4. Factor supplies and factor prices

Let us put the issue of international trade on one side for the moment, and consider the relationship between factor supplies and factor prices within a closed economy -- which we may think of as the OECD in 1970, or the hypothetical modern OECD which we use for our but-for analysis, an OECD which does not have the option of trading with newly industrializing countries. We will continue to assume that this economy produces skill-intensive X and labor-intensive Y using skilled labor S and unskilled labor U. No assumptions will be made about elasticities of substitution in either production or consumption. However, I will assume that tastes are homothetic, so that there is a well-defined elasticity of substitution in consumption, σ_C.

All of this analysis will be conducted for small changes, so that we can make use of "hat algebra"; a hat over a variable means a proportional rate of change.

First, we note the relationship between the relative wage of skilled labor w and the relative price of skill-intensive goods p:

$$\hat{p} = (\beta_X - \beta_Y)\hat{w} \qquad \textbf{(3)}$$

where β_X, β_Y are the shares of skilled labor in the cost of producing X and Y respectively.

We may also note the relationship between relative prices and relative consumption:

$$\hat{C}_X - \hat{C}_Y = -\sigma_C \hat{p} \qquad (4)$$

Now consider how the demand for skilled labor varies with output, holding factor prices and hence factor proportions constant. In that case, we have

$$\hat{S} = \lambda_S \hat{Q}_X + (1-\lambda_S)\hat{Q}_Y \qquad (5)$$

where λ_S is the share of the skilled labor force initially employed in X production; and similarly, we have

$$\hat{U} = \lambda_U \hat{Q}_X + (1-\lambda_U)\hat{Q}_Y \qquad (6)$$

where λ_U is the share of U initially employed in X. Subtracting, we find that the change in relative factor demand holding w (and hence p) constant is

$$\hat{S}-\hat{U} = (\lambda_S-\lambda_U)(\hat{Q}_X-\hat{Q}_Y) \qquad (7)$$

We can turn this around to estimate the effect of factor supplies on output, holding p constant; or better yet, we can now add relative price changes as well, to derive the relative supply equation

$$\hat{Q}_X - \hat{Q}_Y = \frac{1}{\lambda_S - \lambda_U}(\hat{S} - \hat{U}) + \tau\hat{p} \qquad \textbf{(8)}$$

The parameter τ, the elasticity of relative supply with respect to the relative price, is of course not a primitive parameter; it is a function of factor shares and elasticities of substitution. It will turn out, however, that it will be sufficient to use this reduced-form representation.

In a closed economy, production must equal consumption. So (8) and (4) may be combined to yield the response of relative prices to changes in relative factor supplies:

$$\hat{p} = -\frac{1}{(\lambda_S - \lambda_U)(\sigma_C + \tau)}(\hat{S} - \hat{U}) \qquad \textbf{(9)}$$

Finally, from (3) we have the relationship between changes in factor supplies and changes in factor prices:

$$\hat{w} = -\frac{1}{(\beta_X-\beta_Y)(\lambda_S-\lambda_U)(\sigma_C+\tau)}(\hat{S}-\hat{U}) \qquad \textbf{(10)}$$

which may equivalently be expressed as

$$\hat{w} = -\frac{\hat{S}-\hat{U}}{\sigma_A} \qquad \textbf{(11)}$$

where σ_A is the *aggregate elasticity of substitution* between skilled and unskilled labor.[6]

All of this is for a closed economy, and as such is (one hopes) unobjectionable. What researchers on trade and wages have wanted to do, however, is to apply an equation that looks like (11), but to do so for an open economy, and to use changes in "effective" factor supplies due to the factors "embodied" in trade rather than changes in actual factor supplies. Can such a seemingly ad hoc procedure have any validity?

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Notice that substitution between goods in consumption as well as substitution between factors in production enters into the definition of σ_A.

5. The factor content of trade[7]

The factor content approach to estimating the effect of trade on factor prices consists of the following: multiply the trade balance in X by the ratio of S to X in domestic production, multiply the trade balance in Y by the ratio of S to Y; the difference is the reduction in "effective" supply of S, which may be divided by the actual supply to get a percentage change. Similarly, one uses domestic input coefficients and trade balances to compute the increase in the "effective" supply of U. Finally, divide the calculated change in the S/U ratio by some estimate of the elasticity of substitution to get the implied change in the relative wage.

To assess this procedure, let us imagine that was has really happened is the trade opening shown in Figure 6: the economy has acquired the option of trading with new trading partners. Let us also assume (realistically, for North-South trade) that the resulting trade is sufficiently small that we can use calculus to approximate its effects. That is, the changes in consumption, production, relative prices, and relative wages from their autarky levels are small enough that we can usefully do a "linearized" analysis.

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[7] This analysis has a strong affinity with that of Deardorff and Staiger (1988), who derive a general equation relating factor content and relative factor prices in the case of a Cobb-Douglas economy. To my knowledge, however, the result derived here has not been clearly pointed out before.

The trade balances in X and Y may be written as $dQ_X - dC_X$, $dQ_Y - dC_Y$ respectively. The change in the "effective" supply of skilled labor that a factor content analysis would estimate would therefore be

$$dS^e = (dC_X - dQ_X)\frac{S_X}{Q_X} + (dC_Y - dQ_Y)\frac{S_Y}{Q_Y} \qquad \textbf{(12)}$$

or, rewriting, we may say that

$$\frac{dS^e}{S} = \lambda_S\left(\frac{dC_X}{C_X} - \frac{dQ_X}{Q_X}\right) + (1-\lambda_S)\left(\frac{dC_Y}{C_Y} - \frac{dQ_Y}{Q_Y}\right) \qquad \textbf{(13)}$$

where λ_S is the initial share of S employed in the X sector. (Remember that at the starting position consumption and production of X are equal). Similarly, we will estimate that

$$\frac{dU^e}{U} = \lambda_U\left(\frac{dC_X}{C_X} - \frac{dQ_X}{Q_X}\right) + (1-\lambda_U)\left(\frac{dC_Y}{C_Y} - \frac{dQ_Y}{Q_Y}\right) \qquad \textbf{(14)}$$

Subtracting, we will therefore estimate that

$$\frac{dS^e}{S} - \frac{dU^e}{U} = (\lambda_S - \lambda_U)\left(\frac{dC_X}{C_X} - \frac{dC_Y}{C_Y} - \frac{dQ_X}{Q_X} + \frac{dQ_Y}{Q_Y}\right) \qquad \textbf{(15)}$$

But now apply (4) and (8), bearing in mind that actual as opposed to effective factor supplies are being held fixed; we now find that

$$\frac{dS^e}{S} - \frac{dU^e}{U} = (\lambda_S - \lambda_U)(\sigma_C + \tau)\hat{p} \qquad \textbf{(16)}$$

or, substituting the relationship (3) between goods and factor prices, we have

$$\frac{dS^e}{S} - \frac{dU^e}{U} = (\lambda_S - \lambda_U)(\sigma_C + \tau)(\beta_X - \beta_Y)\hat{w} \qquad \textbf{(17)}$$

This is starting to look familiar. In fact, we may finally restate our result as follows:

$$\hat{w} = -\left(\frac{dS^e}{S} - \frac{dU^e}{U}\right)/\sigma_A \qquad \textbf{(18)}$$

which is exactly parallel to (11). The change in factor prices from trade will, indeed, equal the change in "effective" factor supplies

divided by the aggregate elasticity of substitution, just as the advocates of the factor content approach have claimed.

This is an elegant result, but also a somewhat embarassing one. The reactions of trade theorists to the factor content approach have ranged from skeptical to vitriolic. It turns out, however, that the approach is entirely justified in the context of a general-equilibrium model when the trade share is sufficiently small -- as it is.[8]

There are, admittedly, some questions about the way in which factor content analysis has actually been conducted. Some estimates have applied the method to situations in which trade is unbalanced, making it seem as if trade deficits rather than the overall volume of trade is the key factor; Bhagwati and Dehejia (1994) have correctly pointed out that this is wrong, that trade deficits must be discussed in the context of the transfer problem, and that their impact on factor prices, if any, may have little to do with the issues discussed here. One may also question whether reduced-form econometric estimates of σ_A are really reliable. But

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[8] I realized that the factor content approach must be a good approximation while doing CGE-based estimates for Krugman (1995), during the course of which I found that I could guess the results of full equilibrium calculations in advance from the factor content of trade. It is easy to confirm through such experiments that (18) is a very good approximation for trade volumes of the size we are actually discussing.

the general idea that it is useful to estimate the factor content of trade is vindicated. And so is the point that since the changes in "effective" factor supplies associated with measured trade volumes are small compared with either actual changes in these supplies or the apparent changes in factor demand due to biased technical change, trade is unlikely to be the main force driving wages.[9]

6. Conclusions

The assessment of the causes of changes in factor prices is ultimately an empirical matter, and thus the conclusion of recent empirical work that trade has been only a secondary influence while technology has been the main cause is subject to revision if new

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There remains the argument of Wood (1994) that estimates of factor content understate the true impact of North-South trade. This argument depends not only on the claim that the manufactured goods advanced countries import from NIEs are far more labor-intensive than any goods still produced in the North, but on the claim that the elasticity of demand for these goods is very low; in effect, Wood argues that in the absence of manufactures imports from the NIEs, the OECD would have a labor-intensive manufacturing sector producing these goods that is very much larger than the 2 percent of GDP actually spent on such imports. Wood also assumes a very low aggregate elasticity of substitution. Not only are these dubious assumptions (with unitary elasticities of substitution Wood's estimates are comparable to those of other researchers); Lawrence (1995) has shown that Wood's crucial underlying assumption that NIEs have the same technologies as advanced countries cannot be sustained even using his own data.

data or improved estimates come along. What we can say is that the conceptual foundations of this work are sound.

That is, it may turn out that the *prima facie* case that skill-biased technological change has played an important role in the rising skill premium is wrong; but researchers have been right to emphasize the potential importance of that bias. It may turn out that, despite what now seems to be the case, it is possible to construct a quantitatively plausible model that reconciles large distributional effects from international trade with the small volume of that trade; but researchers have been right to see small trade volume as a problem for those who would make trade the main culprit behind falling wages. It may turn out that for one reason or another calculations that show small net factor content of trade are misleading; but such calculations are a valid and useful approach to the problem.

Moreover, we may argue that the way that we can ground such empirical assessments in general-equilibrium trade models is a vindication of such models as practical tools. Indeed, the whole issue of trade, technology, and wages may be regarded as having provided a unique opportunity for trade economists to demonstrate the power and usefulness of their theoretical framework.

Unfortunately, trade theorists as a group have not made very good use of this opportunity. Rather than providing helpful guidance to empirical workers, they have offered unhelpful

criticism, in some cases dismissing as unsound approaches that are in fact entirely appropriate. The factor bias of technological change, which may well be a crucial part of the story, has been dismissed as "irrelevant". The small volume of trade, which is certainly a key fact that any analysis must somehow accommodate, has been declared "immaterial". And economists who have calculated the factor content of trade, a procedure that turns out to be entirely reasonable, have been excoriated as "incompetent".

Why have theorists gone so far off track? Not because they are using the wrong model: the relationships among trade, technology, and factor prices are indeed very well suited for analysis using the standard competitive trade model. What seems to have happened, instead, is that some trade economists have become confused over the role of the standard exercises that are used to explain trade theory in the classroom. What one does when one examines the effect of an exogenous change in world prices, or a unilateral change in technology in a small open economy, is to perform a thought experiment -- a thought experiment whose details have been chosen to lay bare the mechanics of the model, not necessarily to make sense of a real-world issue. Some theorists seem, however, to have identified the canonical thought experiments with the model itself. They thus fail to realize that classroom exercises that explore the effects of technical change in a small price-taking economy do not address the issues posed by

technical change occurring in the OECD as a whole; that the absence of trade volumes in the statement of the Stolper-Samuelson theorem, which implicitly involves a thought experiment in which prices are changed exogenously, does not mean that such volumes are irrelevant to attempts to infer the impact of trade on factor prices when the impact of trade on goods prices is part of the question. And trade theorists -- myself included -- were quick to dismiss factor content calculations as misleading, without making any serious effort to see what they might tell us; did we assume they must be wrong simply because calculating the relationship between factor content and changes in factor prices is not a standard classroom exercise?

There is nothing wrong with addressing policy issues using general equilibrium trade theory. Indeed, that theory has never been more relevant than it is today. But no model will give us the right answers if we are not careful to ask the right questions.

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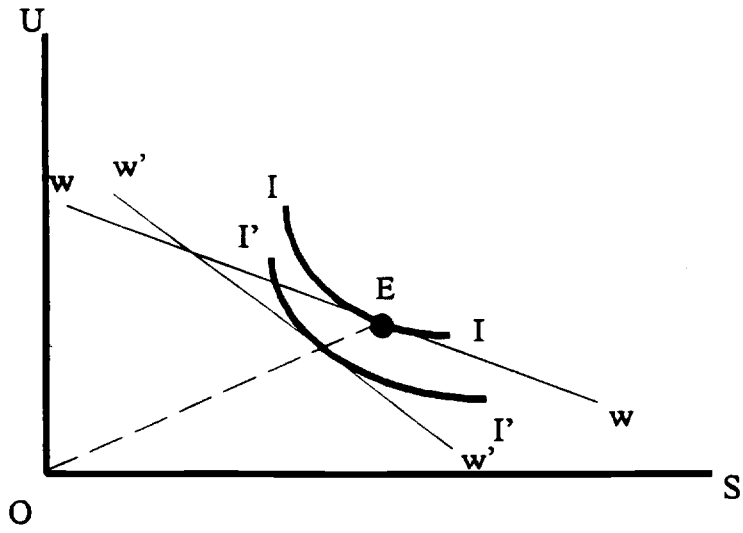


Figure 1

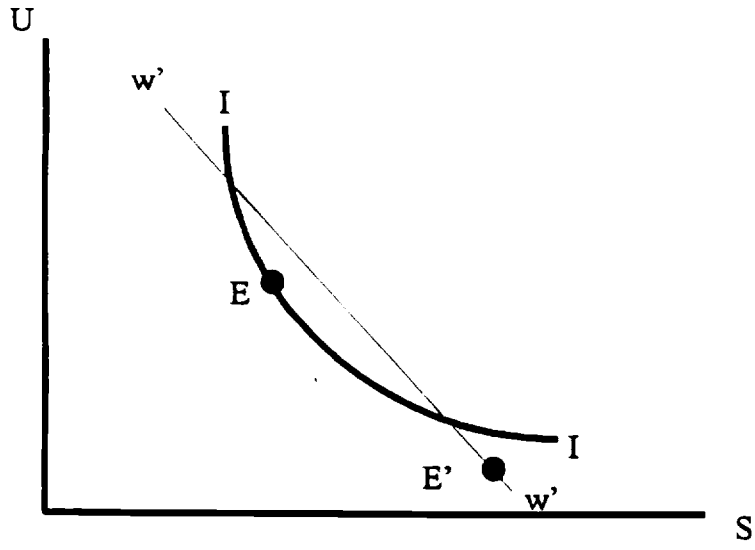
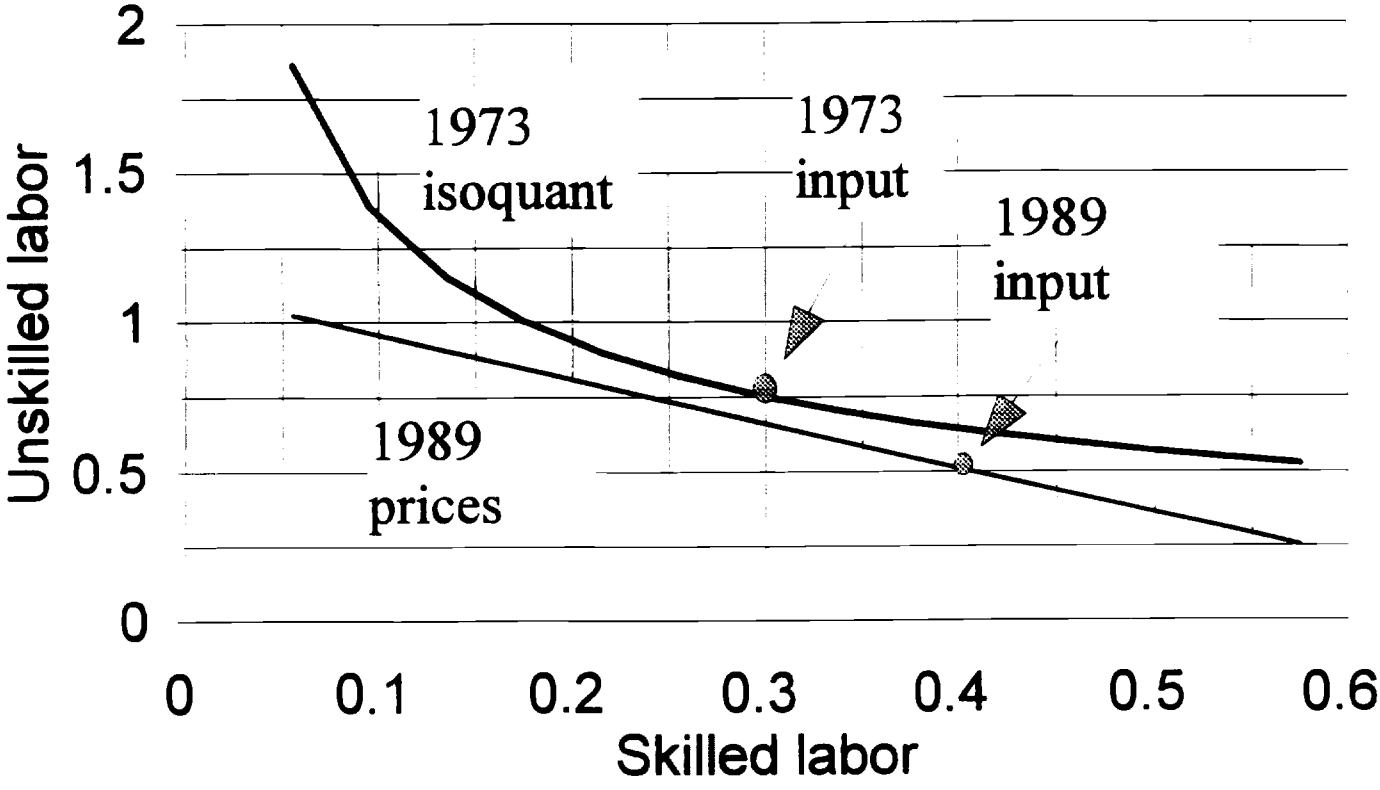


Figure 2

Figure 3


2
1.5
1
0.5
0
Unskilled labor
1973
isoquant
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Skilled labor

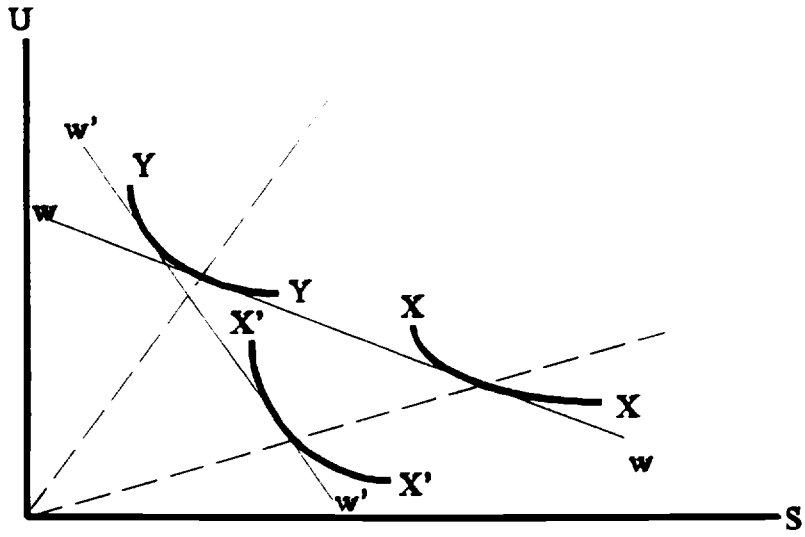

Figure 4

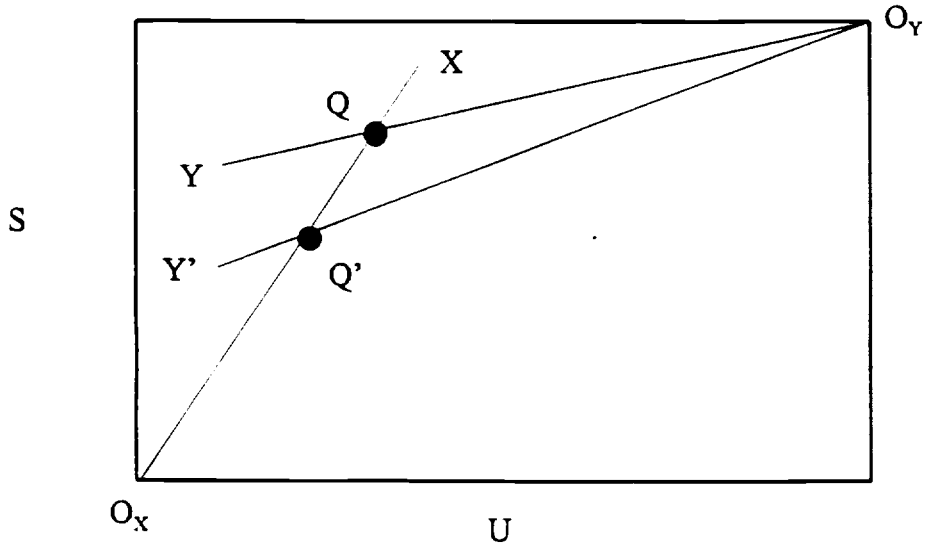

Figure 5

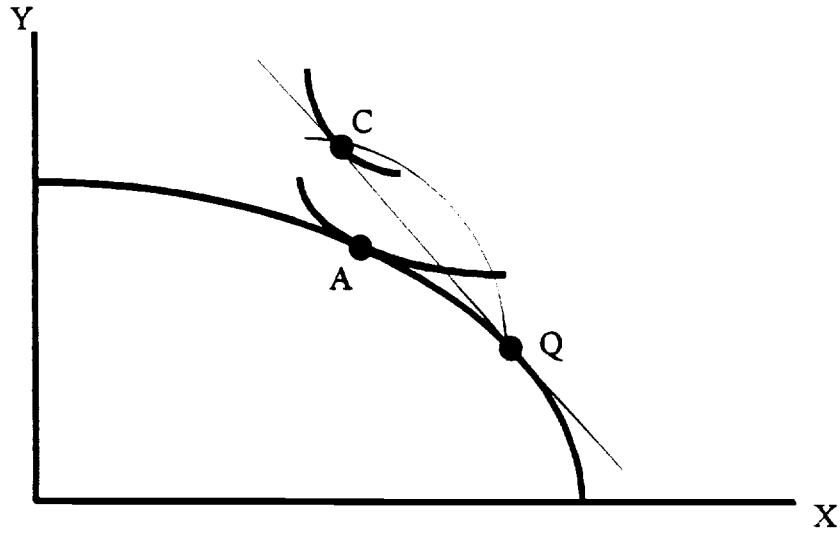

Figure 6