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Globalization: Country and company interests in conflict

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Abstract

Globalization has brought about fundamental change. But, the same theory that shows that free trade is beneficial also shows that globalization can be harmful to at least one of the trading countries. Moreover, with globalization, the interests of a country and its companies may diverge. In this paper, we examine free trade in a globalizing world and identify the key policy issues that economists and industrial leaders, alike, must address in today's interdependent world.

Keywords: Globalization; Free trade; Country; Company; Comparative advantage; Equilibrium; Asian countries

1. Introduction

We base the conclusions of this paper firmly on some of the oldest and most time honored models in economics. But because we live in a globalizing world the questions that we ask of these familiar models are different than those typically asked in the past. As a result, what emerges from this analysis may go against the grain of many economists' general beliefs.

Globalization has brought about fundamental change. Here we note two significant changes, which we will explain more fully as we go along:

(1) The same theory that shows that free trade is beneficial also shows that globalization can be harmful to at least one of the trading countries; and
(2) With globalization, the interests of a country and its companies[2] may diverge.

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[1] Tel.: +1 212 998 8943; fax: +1 212 995 4211.
[2] Examples are global firms such as IBM, G.E., and Intel, which still are headquartered in their country of origin, but have substantial worldwide interests.

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2. Free trade and globalization

We have all learned that free trade between countries, whatever their capabilities, is always beneficial. Even if one country is more productive than another in every product entering into trade, there is still something to be gained for that country in trading with its economically undeveloped partner. Laymen may struggle to understand this, but economists, having absorbed the principle of comparative advantage, accept this as fact.

In a globalizing world, however, we are no longer dealing with a situation in which two countries' productive capabilities are fixed—rather, these are subject to change for both trading partners. The China we traded with twenty years ago did not make semiconductors and automobiles, for instance, but today's China does.

This naturally raises the question: are we better off trading with the old or new China?

Improved productivity in a trading partner may seem to be beneficial to both the home country and the newly developing one, but that is not what economic theory teaches us. A long succession of economists, dating back at least to Professor J.R. Hicks's inaugural address at Oxford University, have pointed out that a trading partner's improved productivity in the industries that the home country exports can be harmful to the home country.

Our own work, stretching over many years (Gomory, 1991, 1994; Gomory & Baumol, 1992, 1994, 1995, 1996a, 1996b, 1997a, 1997b, 1998a, 1998b, 2001) illuminates the conditions under which economic development in a trading partner can be harmful, or alternately, helpful to the home country.

3. The simplest example

To see that an undesirable outcome for at least one of the trading countries can occur, as Professor Paul Samuelson pointed out in 2004, we need look no farther than the classical, Ricardian-based England–Portugal textile–wine model.

Here we assume that England is productive in textiles and unproductive in wine,[3] while Portugal is unproductive in textiles, but productive in wine. We also assume that in both countries the demand for textiles exceeds the demand for wine.

Figs. 1 and 2 show the two countries in three different cases: (1) autarky, (2) free trade, and (3) globalization. In the case of autarky (no trade), England is productive in textiles, making and consuming a large quantity of these.

In contrast, the portion of the English workforce that engages in wine production is relatively unproductive—there is little wine produced and, therefore, little wine consumed. The situation in Portugal is similar, but, of course, reversed—Portugal has plenty of wine, but few textiles.

In the second case, free trade, the entire English workforce produces textiles, and the entire Portuguese workforce makes wine. The portion of the English workforce that made wine in autarky now makes textiles and trades that production for wine, and the former Portuguese textile workers are now making wine. The familiar and beneficial result is that the English consume the same amount of textiles as before, but have much more wine. Similarly, the Portuguese have the same wine consumption as before, but more textiles.

In the last case, globalization, Portugal realizes that it is better to produce the more demanded good and learns to make textiles with a productivity level matching that of England.[4] The new

[3] All of the relevant numerical values for this model are given in Appendix A.

[4] This is the case mentioned by Professor Hicks, in which a trading partner improves in a home country's export industry.

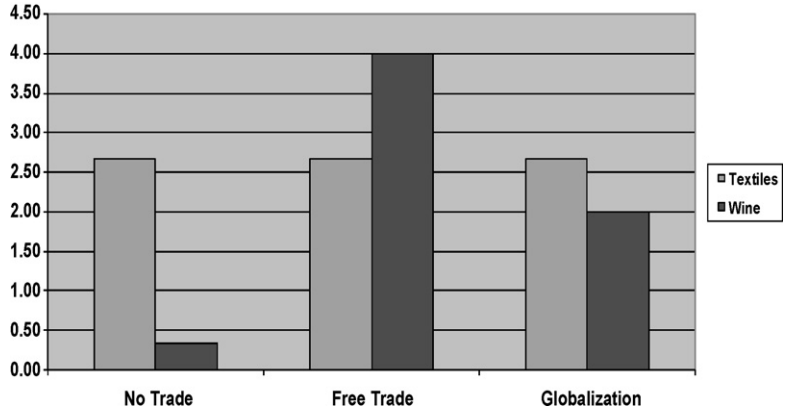

Fig. 1. England's consumption.

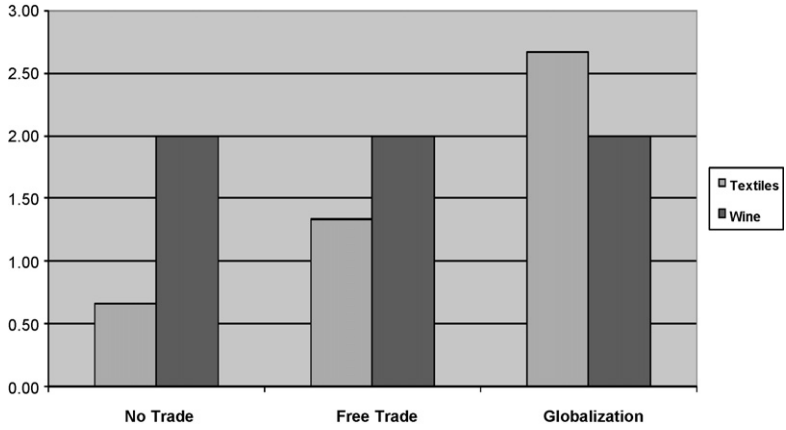

Fig. 2. Portugal's consumption.

equilibrium result is that England still specializes in textiles, but it now supplies three-quarters, rather than all, of the world's textiles. Meanwhile, Portugal splits its workforce, with one-third engaged in textile production and two-thirds making wine. At this new equilibrium, Portugal supplies one-quarter of the world's textiles and all of the world's wine.

England still produces as many textiles as before, but that output is now a smaller share of the world's output, while Portugal's share of world output has increased. Therefore, the terms of trade[5] are no longer as favorable for England; it gets less wine than before for its textile exports. As a result, wine consumption in England decreases, while its textile consumption remains the same. England clearly has been hurt by Portugal's economic development. Portugal, on the other hand, has increased its textile consumption, while its wine consumption has remained the same. Portugal has gained from globalization.

[5] In this Ricardian model, the terms of trade reflect how many hours of Portuguese labor one hour of English labor can purchase. See Appendix A for a fuller explanation.

When can we expect an outcome like this, in which a developing country gains and its trading partner loses from globalization? When can we expect a result that benefits both countries? In the next section, we address these questions.

4. The general case: statement and analysis

As described in Gomory and Baumol (2001), the general conclusion can be stated as follows:

The development (increased productivity) of an underdeveloped trading partner usually is good for the home country—up to a certain point. After that, further development of the trading partner is harmful to the home country.

To explain more precisely what this means, we use the standard Ricardian model of international trade to analyze the case of two countries trading with each other in n industries. The size of the labor force in Country 1 is represented as L_1 and that of Country 2 as L_2. The countries' spending preferences are Cobb–Douglas in form, so the spending on good i by Country J is a fixed fraction ($d_{i,j}$) of its national income.

On the production side, the quantity of good i produced in Country J is $q_{i,j}$, and $q_{i,j}$ is linearly related to the labor $l_{i,j}$ input by $q_{i,j} = e_{i,j} l_{i,j}$. By changing the productivity coefficients $e_{i,j}$, we get different equilibria. In the England–Portugal example noted above, for instance, we moved from the free trade equilibrium to the globalization equilibrium by changing Portugal's productivity coefficient in textiles.

The set of productivity coefficients, $e_{i,1}$, reflects Country 1's state of development, while the set of productivities, $e_{i,2}$, reflects Country 2's state of development. However, productivity is always bounded by the state of the art and sometimes, as in the case of oil, by natural resource limitations. Therefore, for each country in each industry, there is a maximum possible productivity $emax_{i,j}$, and the different possible states of development, $e_{i,j}$, must always satisfy $e_{i,j} \leq emax_{i,j}$.

In our analysis, for each model specified by fixing the number of industries, n, and the maximum productivity levels, $emax_{i,j}$, we will consider all of the equilibria that result from all *possible* productivities, i.e., all $e_{i,j}$ that are less than or equal to $emax_{i,j}$. The different possible values of $e_{i,j}$ correspond to different states of a country's development. To determine the equilibrium outcomes for each set of $e_{i,j}$, we will use a standard set of equilibrium equations described in Appendix B.

5. The basic graph

For any given vector $\varepsilon = \{e_{i,j}\}$ of possible productivity parameters in our n industries, there is an equilibrium outcome. At that equilibrium, there will be a national income Y_j and a utility level U_j for each country. Graphs that plot relative national income, rather than actual income, turn out to offer several advantages—so, from Y_j we compute relative national income:

$$Z_1 = \frac{Y_1}{(Y_1 + Y_2)} \text{ and } Z_2 = \frac{Y_2}{(Y_1 + Y_2)}.$$

We can then plot this equilibrium as a pair of points in a diagram that displays Z_1 and Z_2 horizontally and the utilities of the two countries, U_1 and U_2, on the right and left vertical axes, respectively.[6] Z_1, which we can think of as the share or percent of world income earned by Country 1, can range from 0 to 1 (100%); Z_2 is always the remaining share, $1 - Z_1$.

[6] Clearly, one can always work back and obtain the actual Y_1 and Y_2 from Z_1 and Z_2.

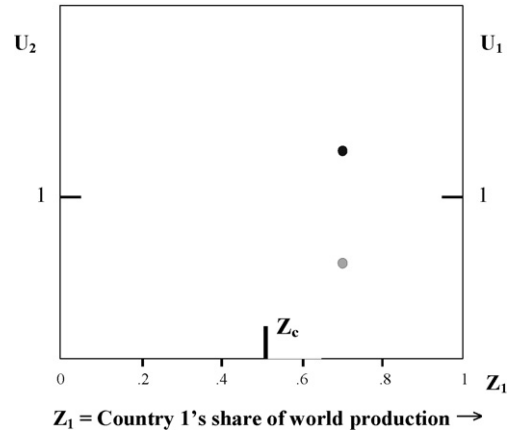

Fig. 3. One equilibrium.

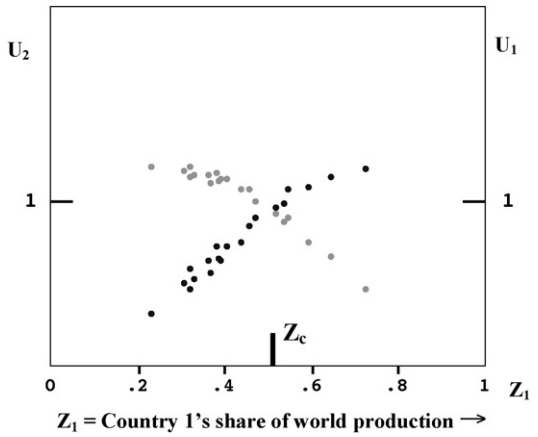

Fig. 4. Eighteen equilibria.

Fig. 3 depicts this equilibrium. The black dot represents Country 1's utility measured against the right vertical axis, and the grey dot represents Country 2's utility measured against the left vertical axis. The unit height on each axis is the utility that would be obtained if there were no trade, and the country made everything for itself with maximal possible productivity.

It is perfectly possible—indeed common—for a country's equilibrium trade outcome to be less than this autarky outcome. That simply indicates that there are many industries in which the country does not attain the maximum possible productivity. Industries in underdeveloped countries, for instance, rarely achieve maximum possible productivity.

This method of representing equilibria, allows us to represent many different equilibria in a single graph. In Fig. 4, we show 18 equilibria resulting from a model with 11 traded goods ($n = 11$). The different equilibria were randomly chosen from the range of possible productivity levels.[7]

[7] The Z_C that appears in the diagram indicates the shares of world income that emerge from the equilibrium in which both countries are at maximum productivity in all industries.

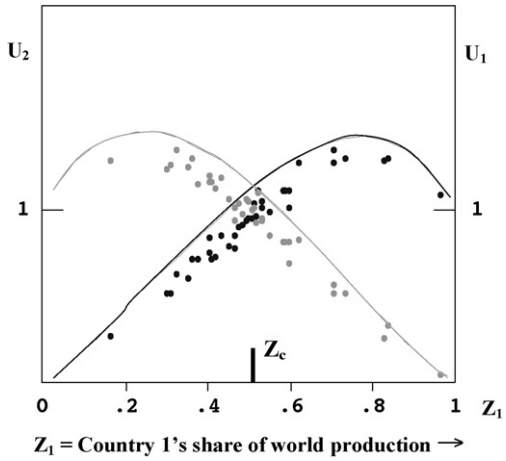

Fig. 5. All possible equilibria.

In this figure, we see that the equilibria that yield the most utility for Country 1 tend to yield a low utility for Country 2, and vice versa. We also see that Country 1's utility increases with Z_1, its share of world income. Similarly, Country 2's utility, U_2, increases with its share of world income, $Z_2 = 1 - Z_1$.

Are these outcomes general phenomena, or do they result only from this special example and the special choices of $e_{i,j}$? To answer this question we turn to an analysis that enables us to deal with *all* of the possible equilibria of a model with n number of traded goods.

6. All possible equilibria

In our analysis, for each n and set of $emax_{i,j}$ we will now consider all possible productivity levels—that is, all productivities $e_{i,j}$ with $e_{i,j} \leq emax_{i,j}$. We have developed mathematical methods that enable us to carry out this analysis.

The result of our analysis is shown in Fig. 5, which contains all possible equilibria for an 11-industry model with two countries of the same size and a set of maximal productivities.

The black line marks the upper boundary of a region filled with black dots, each representing one of the equilibrium outcomes for Country 1. Several of the black dots are shown as examples. Each black dot—whether shown individually or not—has a counterpart grey dot from the same equilibrium. The grey line marks the upper boundary of a region filled with these grey dots. Again, only a few of these dots are shown individually, as the counterparts of the black dots. However the region on or below the grey line is filled solidly with grey dots—the counterparts of the black dots. The possible equilibrium pairs' utility value for Country 1 is shown on or below the black line, and their equilibrium values for Country 2 appear on or below the grey line. In Fig. 6, which depicts the same 11-industry example, we have marked the best possible equilibrium for Country 1 with a large black dot at the peak of the black boundary curve. The corresponding utility for Country 2 is indicated by the large grey dot directly below. Similarly, the large grey dot at the top of the peak of the grey boundary curve shows the best possible equilibrium for Country 2. The corresponding utility value for Country 1 is represented by the large black dot directly below.

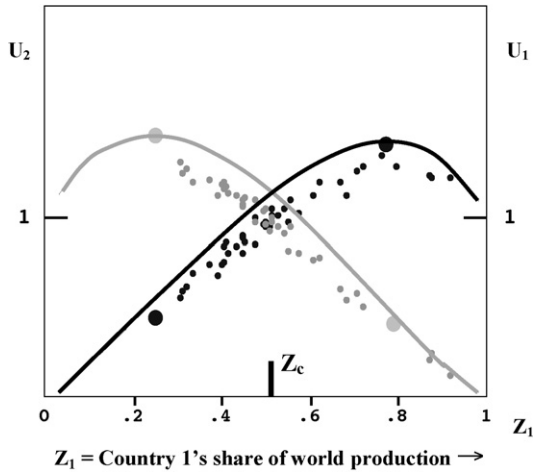

Fig. 6. Conflicting equilibria.

Note that, in both cases, the best equilibrium for one country is a poor one for the other. It can be shown that these characteristics are not uniquely generated by this 11-industry model, but hold generally.

7. The upper boundary of the equilibria: general statement

Remarkably, all models with a reasonably large number of industries (usually eight or more) and with any but the most extreme and artificial choices of maximal productivities exhibit essentially the same boundary shape. As such, the following general statement describes these boundaries:

For models with a reasonable number of industries, the exact regional boundary for Country 1 can be approximated by a smooth curve with height 0 at $Z_1 = 0$, which then rises to a single peak and thereafter descends to the utility level that Country 1 obtains in autarky. Similarly, the boundary for Country 2 starts at 0, then at $Z_1 = 1$ rises to a single peak to the left of the Country 1 peak (as Z_1, decreases), and finally descends to Country 2's autarky value. Thus, in all cases, the best outcome for one country is a poor one for the other.

So far, we have illustrated the upper boundary curves with countries of equal size. The same statement holds for two countries of markedly different size. In Fig. 7, Country 2's labor force (grey) is three times the size of the labor force in Country 1. Although the boundary curves look superficially different, as compared with those in the model depicting countries of equal sizes ($L_1 = L_2$), we still observe the properties described in the general statement. More specifically, the best outcome for one country is still a poor one for the other.

Every step of the mathematical analysis that leads us to this conclusion has a specific economic meaning, which is discussed briefly in Appendix C. Moreover, this outcome also makes sense from a direct, intuitive perspective, as we describe in the next section.

8. World output

In addition to questions about Country 1 and Country 2, it is important to consider how the world as a whole fares at the various equilibria. In Fig. 8, which is a different example, the dome

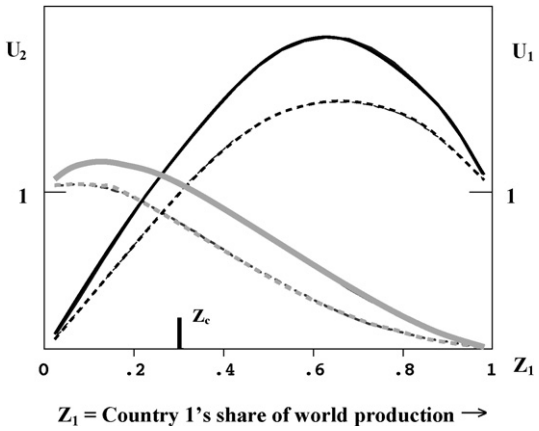

Fig. 7. Countries of unequal size.

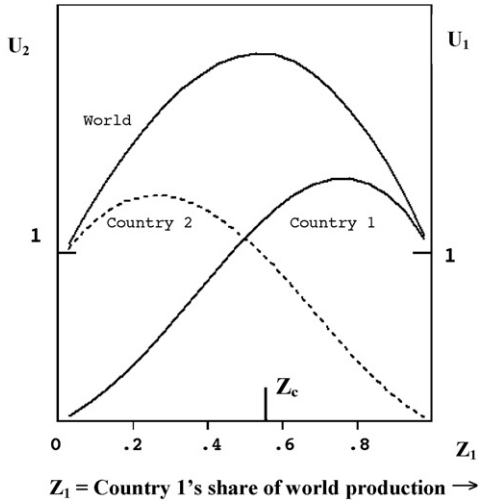

Fig. 8. World, Country 1, and Country 2.

shaped curve represents the utility of total world production. If the two countries shown have the same utility function, we can use that to evaluate world output; if they are different, we can use one or the other function.

In Fig. 8, the total world utility is maximized not at the equilibrium that is best for Country 1, nor at the equilibrium that is best for Country 2, but somewhere in between. It makes sense intuitively that the equilibrium obtained when all industries in both countries are at their maximum productivities in every industry would also be the equilibrium[8] at which total world output, reasonably measured, is maximized.

This, in turn, intuitively explains the boundary shapes for Country 1 and Country 2. If we assume that world output is maximized approximately at Z_C, what can we say about Country 1's

[8] Note that the country shares at this equilibrium are marked by Z_C in all of our diagrams.

boundary curve just to the right of Z_C? Consider a point slightly to the right of Z_C on the Country 1 boundary curve. Country 1's share of world output increases because of the larger Z_1, but the utility of world output is almost the same as it is at Z_C, its maximum, where the boundary curve is flat. Therefore, at this new point, we expect that Country 1's utility has increased, which means it is getting a larger share of a "pie" that is almost the same size. Country 1's utility will continue to grow as Z_1 increases—until the world boundary's steep decline outweighs Country 1's increase in share. At this point, Country 1's boundary curve will turn down, ending at a height of 1 at $Z_1 = 1$.

This discussion also highlights another key point: neither country is motivated to attain the best outcome for the world. Even if this outcome were obtained, both countries likely would be motivated to move away from it in opposite directions, in search of better national outcomes. We will return to world outcomes at the end of this paper, but first we discuss further aspects of our basic graph and of the national outcomes it depicts.

9. Regions of maximal productivity: undominated (Pareto) equilibria

In our standard diagram, the dots representing equilibria at which little is produced (i.e., those with small $e_{i,j}$ in many industries) tend to be low, indicating low utility. In contrast, equilibria having many of their $e_{i,j}$ near their $emax_{i,j}$ will tend to be near the region's upper boundary. If, at some equilibrium, neither country is at its maximum possible productivity in a particular industry, we can multiply those productivity numbers in both countries by a factor, $r > 1$, and achieve a more beneficial equilibrium.[9] At the new equilibrium, the amounts of labor are unchanged in each industry, but more goods are produced. Both countries produce and consume an equal or greater quantity of every good at this equilibrium, and it dominates the old one. Consequently, the only "undominated equilibria" are those at which one or the other country is maximally productive in each industry. As such, an equilibrium is a *maximal productivity equilibrium*—that is, it yields the greatest utility—if, within each industry, one country is producing goods at its maximum level of productivity. Our methods allow us to calculate the boundaries of the regions in which the maximum productivity equilibria lie, and Fig. 9 shows the regions of maximal productivity for the 11-industry model. Note that all maximal productivity equilibria lie in the region of maximal productivity, but that *not all* equilibria within that region are maximal productivity equilibria.

In Fig. 10, we divide the regions of equilibria of Fig. 9 into sub-regions, which we refer to as "regions of conflict" and "regions of mutual gains."

In the far left region of mutual gains, if Country 1—usually an underdeveloped country with a small world market share—increases some of its productivities and moves to a new equilibrium with a larger share of world income (i.e., a larger Z_1), utility for both countries will generally increase. But in the next region—the region of conflict, an increase in Country 1's share of income increases its own utility, while decreasing that of Country 2. In the third region, further increases on Country 1's share decrease the utility of both countries.

All of this leads us to conclude that a trading partner's rise in some productivity level can be either helpful or harmful to the home country—depending on the trading partner's state of development. If the trading partner is undeveloped, for instance, its further development initially will be helpful. However, as the trading partner continues to develop, the beneficial effect on the home country decreases and eventually becomes negative. This changeover from helpful to

[9] It can be seen easily from the equations of equilibria that this solution always constitutes an equilibrium.

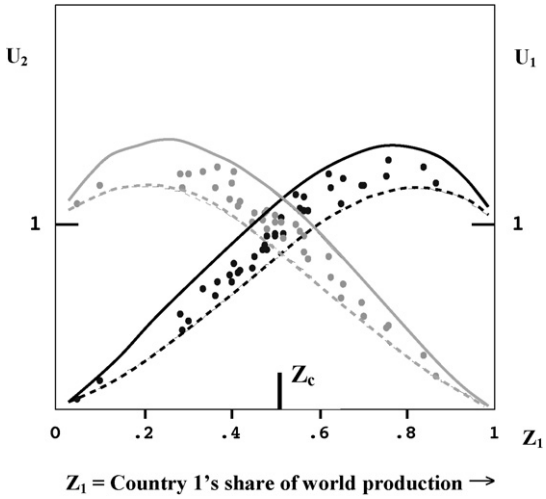

Fig. 9. Maximal productivity regions.

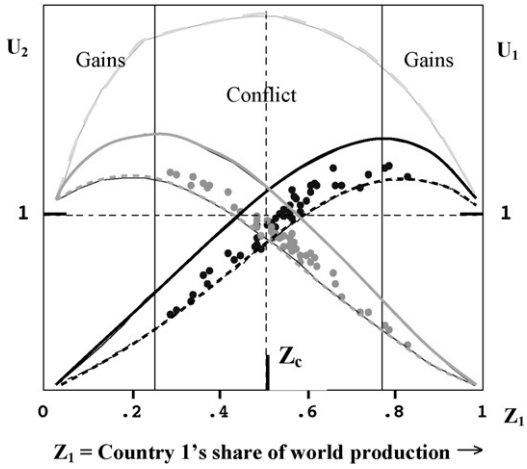

Fig. 10. Regions of mutual gain, regions of conflict.

harmful development among equally sized countries occurs when the wage in the trading partner reaches about one-third of the home country's wage, as Fig. 10 shows. Countries of different sizes, however, will experience a slightly different dynamic. In the case of a small country trading with a large country, as Fig. 7 shows, the changeover comes much earlier, as the large, relatively backward country develops.

10. General policy implications

What are the implications of our analysis for policy design? As we have seen, in a free-trade world, there are many possible equilibria with vastly different outcomes for the countries involved. In the modern word, good equilibria more often are *created* rather than *bestowed* by nature. As such, there is much that countries can do to affect their trading outcomes.

This reality differs markedly from Ricardo's world, in which natural capabilities played a much larger role. Certainly, there are natural resources—oil is a good example—that still bestow a natural advantage on countries in which they are found. But in today's world, semiconductors, for instance, can be made anywhere, and even in a traditional industry like automobile production, success does not require an advantage in natural resources, as Japan has demonstrated.

11. Policy implications for developing countries

Our analysis shows that all but the most highly developed countries gain utility by improving their share of the total world output of goods and services. The payoff is obvious, but the methods for getting there may not be. Specifically, how should a developing country go about improving its share of world output in order to reach a better equilibrium outcome? One approach is to learn and compete in more and more industries on the basis of native capital and know-how. Another is to make it attractive for foreign capital and know-how to move into a country.

Many Asian countries have taken this latter route. These countries make it profitable for foreign companies to move their operations to Asia. In labor-intensive industries, Asian host countries' low wages alone may be enough to enhance a company's profits. For other industries, host countries may give companies special tax treatment, share the cost of facilities, or even supplement employee wages—whatever it takes to assure a company's profitability. Disc-drive and semiconductor manufacturing, for instance, have moved into Asian countries, enabling them to take a large part of the world market for these important goods. These countries have succeeded because they aligned companies' profit goals with their own national goals of increasing output and, thus, moving to a better trade equilibrium.

These fast-developing Asian countries have managed to satisfy both national and company objectives: larger GDP for host countries and bigger profits for companies. In contrast, U.S. companies are neither required nor encouraged to take into account the impact of their business decisions on the U.S. This strategy may not be a reasonable one for the U.S in a globalizing world.

12. Policy implications for the U.S.

The U.S. often formulates its response to challenges like these in terms of science and innovation—by boosting R&D efforts or enhancing linkages between universities and corporations so that innovative ideas can move more rapidly into practice. Although they were successful in past decades, these responses are not as effective as they once were. With globalization, close university ties to global corporations, such as Intel or Microsoft, merely spread new research results around the world. As such, new technology may result in higher productivity and GDP growth abroad, rather than in the U.S.

If the U.S. is to maintain or improve Americans' standard of living, U.S. productivities must continue to improve, or run the risk of actual decline. Requesting more money for R&D or improving primary and secondary education are two possible ways in which the U.S could respond. However, improving education is both slow and difficult to achieve, and, moreover, such improvements in education are unlikely to be so profound that they turn out Americans who are more productive than the three or four Asians who can be hired for the same wage. Proposals of this sort regarding education and R&D can be helpful, but if such measures are taken as the sole response to America's productivity problem, they can even be harmful.

Effective responses must include measures that tackle the problem more directly. Asian countries have made it profitable for foreign—often U.S.—corporations to create high-value-added

jobs in their countries by offering tax and other incentives that make it *profitable* for corporations to relocate such jobs to Asia. This suggests that the U.S. should consider incentives that reward companies in the U.S. for the same vital activity. If the U.S. wants to attract and retain high-value-added jobs, it should have, in its arsenal of responses, ways of rewarding companies for producing such jobs. The U.S. should reward that result, whether it is attained through more R&D or through just plain American ingenuity applied in any way in any business.

The U.S. does not have—nor seemingly does it want—the government entities that many Asian countries have employed to make deals with global corporations. However, the U.S. does have a tradition of tax incentives—such as an R&D tax credit—that reward business behavior that benefits the national interest.

Using such across-the-board incentives, rather than making individual deals with specific companies, would be a response much more in keeping with both traditional U.S. approaches and with the actual capabilities of the federal government. A corporate tax rate scaled by the value added per full time employee for corporations operating in the U.S. is one such idea. This proposes that a company with high value added per U.S. employee would be subject to a low tax rate, while a company with low value added per U.S. employee would pay a higher rate. This would provide an incentive for companies with high-value-added jobs to relocate to or remain in the U.S., and it is also an action that could be made revenue neutral.

Many incentives—some natural and others much less so—have worked in favor of the U.S., helping to create a long history of economic growth. The U.S. has a great range of natural resources and a remarkable culture of entrepreneurship that helps to translate ideas into reality, and in doing so, provides rich rewards for that accomplishment. In the past, many American corporations have recognized that they could benefit by investing in ways that assist their U.S. workforce, in order to increase the productivity of the firms. *The U.S. needs to consider incentives, such as the corporate tax mentioned above, that realign corporations' profit motives with the larger interests of the country.* We see this as a major problem facing the U.S., but we also believe there are actions—most still largely unexplored—that could significantly benefit the country.

We have shown that globalization is not automatically benign for all of the affected countries. In particular, we strongly believe that the U.S. needs a new economic strategy that aligns corporate and national goals and reflects the realities of a globalizing world.

13. Policy implications: beyond U.S. goals

Because developed countries, in general, have the same problem as the U.S., it is worthwhile to frame this question in a more general form: in a globalizing world, how can developed countries find ways to continue to progress, while new economies develop? More importantly, how can all countries enhance world output while escaping their natural tendency to enrich themselves at their neighbor's expense? As our analysis has shown, this can be a built-in consequence of the structure of world trade.

We need to go beyond discussions of free trade and protectionism to find new ways to meet the unique challenges that arise in a world of globalized free trade. We hope economists will take up these new challenges and find new ways to attain these important and highly desirable goals. New economic insight is badly needed to create new options for the economic and industrial leaders of our country and of other countries in today's interdependent world.

Appendix A. Numerical values for the England Portugal model

Demand (Cobb–Douglas) is 2/3 for textiles and 1/3 for wine in both countries. Both countries have labor forces of size 1. As such, the equilibrium outcomes for the three cases are as follows:

Autarky

	Textile productivity	Wine productivity	Textile consumption	Wine consumption	Textile labor	Wine labor	Relative wage[10]
England	4	1	8/3	1/3	2/3	1/3	n/a
Portugal	1	6	2/3	2	2/3	1/3	n/a

Free trade

	Textile productivity	Wine productivity	Textile consumption	Wine consumption	Textile labor	Wine labor	Relative wage
England	4	1	8/3	4	1	0	2/3
Portugal	1	6	4/3	2	0	1	1/3

Globalization

	Textile productivity	Wine productivity	Textile consumption	Wine consumption	Textile labor	Wine labor	Relative wage
England	4	1	8/3	2	1	0	1/2
Portugal	4	6	8/3	2	1/3	2/3	1/2

The output of each country in each good is obtained by multiplying the labor force employed (labor column) by the productivity. For example, in the globalization case, Portugal produces a quantity of 4/3 of textiles and England produces 4.

The price of each good is the wage (per hour) divided by the productivity (units per hour).

We can verify that these numerical values satisfy the equilibrium conditions of Appendix B.

Appendix B. The model and equilibria

B.1. Introduction

In our standard Ricardian model, we assume that there are two countries and n industries. The quantity, $q_{i,j}$, of good i produced in Country J is determined by the production functions $e_{i,j}\ l_{i,j}$ that are linear in the labor input $l_{i,j}$. Each of the two countries participating in trade has a given utility function of Cobb–Douglas form[11] with demand parameters $d_{i,j}$. The size of labor force L_j of each country and n, the number of industries in this world, are fixed. A single Ricardian model is then completely specified by its vector of productivity coefficients $\varepsilon = \{e_{i,j}\}$. It is the effect of changes in this productivity vector ε on the welfare of the two countries that we will analyze.

Our analysis throughout requires us to find equilibria. Next, we describe our standard equilibrium conditions.

[10] As there is no trade, there is no relative wage, and the wage level in each country can be set arbitrarily.

[11] Specifying the demand is necessary to permit explicit computation and provide *quantitative* results. Specifying it as Cobb–Douglas simplifies the computations. However there are arguments that indicate that that many of our *qualitative* results hold without the Cobb–Douglas assumption.

B.2. Equilibrium conditions

For any given vector of productivity parameters, $\varepsilon = \{e_{i,j}\}$, there is a stable equilibrium giving a national income, Y_j, and a utility, U_j, for each country. From the Y_j we can compute *relative* national income, $Z_j = Y_j/(Y_1 + Y_2)$. This is Country J's relative national income (Country J's *share*). We normalize analogously all of our pecuniary expressions, so p_i, the price of good i, and w_j, the wage in Country J, are also divided by total income, $Y_1 + Y_2$. Clearly we always have total world income, $Z_1 + Z_2 = 1$. Country J's *consumption* of good i is denoted by $y_{i,j}$ and its *production* of good i by $q_{i,j}$. Country J's *production share* or *market share* of world output of good i is represented by $x_{i,j} = q_{i,j}/(q_{i,1} + q_{i,2})$, so that the vector $x = (x_{i,j})$ describes the pattern of production. We can now describe our rather standard equilibrium[12] conditions:

First, national income, or consumption Z_j in Country J, must equal the total value of the goods produced in that country. With a Cobb–Douglas utility, each country spends $d_{i,j}Z_j$ on good i, so total world expenditure on good i is $(d_{i,1}Z_1 + d_{i,2}Z_2)$. Since the fraction produced in each country is $x_{i,j}$, the balance of the value of production and consumption required for each country is:

$$\sum_i x_{i,j}(d_{i,1}Z_1 + d_{i,2}Z_2) = Z_j. \tag{B.1}$$

Second, we have a zero-profit condition. World expenditure on Country J's output of good i all goes into the wages of the labor, $l_{i,j}$, employed in that industry, so:

$$w_j l_{i,j} = x_{i,j}(d_{i,1}Z_1 + d_{i,1}Z_2) \tag{B.2}$$

Third, the full-employment requirement for each country is expressed as the condition that the wage rate multiplied by the country's total labor force equals national income (the wage rate condition):

$$w_1 L_1 = Z_1, \quad w_2 L_2 = Z_2 \tag{B.3}$$

Fourth, we have the requirement that, for each good, the quantity supplied equals the quantity demanded—or equivalently, that the value of the output of good i at the equilibrium price, p_i, equals the amount consumers are willing to spend on it:

$$p_i(q_{i,1} + q_{i,2}) = d_{i,1}Z_1 + d_{i,2}Z_2 \text{ or } p_i q_{i,j} = w_j l_{i,j} \tag{B.4}$$

where the second form of (B.4) follows directly from the first by multiplying through by $x_{i,j}$ and using (B.2).[13] The second form of (B.4) implies that if Country J is an actual producer in industry i, $p_i = \frac{w_j}{e_{i,j}}$.

Finally, we have the conditions that require that in each industry, production (i.e., market share) is always assigned to the producer or producers with the lowest unit cost. For example, if,

[12] What we describe as equilibrium is sometimes called a *stable* equilibrium.

[13] If Country I is a producer, we have $q_{i,j} \neq 0$. Then $p_i q_i = w_j l_{i,j}$ implies $p_i = w_j l_{i,j}/q_{i,j} = w_i/e_{i,j}$.

in industry i, $(w_1/e_{i,1}) < (w_2/e_{i,2})$, then $x_{i,1} = 1$ and $x_{i,2} = 0$. More generally:

$$\begin{aligned}
&\text{if Country 1 unit cost } \left(\frac{w_1}{e_{i,1}}\right) < \left(\frac{w_2}{e_{i,2}}\right) \text{ then } x_{i,1} = 1 \text{ and } x_{i,2} = 0\\
&\text{if Country 1 unit cost } \left(\frac{w_1}{e_{i,1}}\right) > \left(\frac{w_2}{e_{i,2}}\right) \text{ then } x_{i,1} = 0 \text{ and } x_{i,2} = 1\\
&\text{if unit costs are equal } \left(\frac{w_1}{e_{i,1}}\right) = \left(\frac{w_2}{e_{i,2}}\right) \text{ any } x_{i,1} + x_{i,2} = 1 \text{ is allowed.}
\end{aligned} \tag{B.5}$$

It is the actual producer's unit cost that determines the price, p_i. The conditions (B.5) include the familiar comparative advantage criterion.

It is easily shown that at equilibria satisfying the preceding conditions, trade must also be in balance, and the exchange rate, or terms of trade, is w_1/w_2.

Appendix C. The shapes of the boundary curves

This appendix gives another explanation, in economic terms, of the shape of the region of equilibria for each country. While this explanation is rendered in words, using economic terms, the mathematical analysis in Gomory and Baumol (1998a, 1998b), for example, exactly mirrors this explanation. In the mathematical analysis, working from the equations of equilibrium, we find a mathematical expression for the derivative of the boundary curve. Each term in this expression for the derivative corresponds to one of the elements of the explanation we give here.

Why would we expect the expression for the boundary of Country 2, for example, to have the characteristic shape we always see? Let us start at some equilibrium on the Country 2 boundary with share value, Z_1, and consider the effect of moving to a very nearby boundary equilibrium with a somewhat larger Z_1 value, where Country 1 has a larger share of the value of world output. To get to this new equilibrium with this larger Z_1 value, some industry—industry i, or part of industry i—moves from being produced in Country 2 to being produced in Country 1. The transfer from Country 2 occurs because (after a change in the productivity coefficients) Country 1 can make good i better or more cheaply.

The availability of this better or cheaper good is a gain for the consumers in Country 2. However, there is a second effect. Since, at this new equilibrium, Country 2 makes a smaller share of the world's goods, the terms of trade shift against Country 2, and, due to rising wages in Country 1, the goods Country 2 was already getting from Country 1 become more expensive. Meanwhile, there is no change in the price to Country 2's consumers of the goods that country was already making and continues to make.

Suppose that our initial equilibrium was one at which Country 1 was relatively undeveloped (i.e., its Z_1 value is small). The undeveloped Country 1 initially supplied few goods to Country 2, so when Country 1's wages go up and the goods it was already exporting become more expensive for Country 2's consumers, the change is not very consequential. Under these circumstances the net effect of Country 2 losing this industry, but getting the shifted product at a reduced price, could easily be a net benefit to its consumers.

If, however, Country 1 is well developed, with a larger Z_1 value, Country 2's loss of an industry may well have negative effects on Country 2. First, in terms of trade effects, the higher prices for Country 1's goods will be felt on the larger set of goods that Country 2 gets from Country 1.

In addition, the gain to consumers in Country 2 from the transferred—and now more efficient—industry is likely to be smaller. The industries that have already shifted from Country 2 to Country 1 to attain large Z_1 values are the ones in which Country 1 has a larger advantage. The industries Country 2 has retained up to this point are the ones it is best at, so Country 1's advantage in these industries is likely to be small. As successive industry shifts from Country 2 to Country 1 occur, Z_1 will become larger, and Country 2 will feel the larger trade impact of further industry loss. Meanwhile, for Country 2's consumers, the initially positive effect of the shifted industries will decrease.

In sum, with increasing Z_1 values, we would expect to see first a benefit to Country 2 and then eventually a negative effect from the increasing development of Country 1. The country curves portray this progression.

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