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"Are All Technological Improvements Beneficial? Absolutely Not"

by

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Are All Technological Improvements Beneficial? Absolutely Not

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Abstract: This paper shows, using a simple model, that wasteful innovations may result in a loss-loss situation where no country experiences an increase in welfare. If some countries introduce innovations that result in harmful effects on other countries, it may cause the adversely affected countries to retaliate by imposing impediments to international trade. In a globalized and integrated World economy, such policies can only harm the countries involved. Thus, it is in both countries' best interest to encourage sustainable coordination between policies in order to better their own citizens, as well as the World's aggregate welfare.

Keywords: International Trade; Samuelson; Gainers and Losers from Trade; Technological Improvements; Concealed Technological Improvements; Pareto Improvements in Production and Consumption; Nash Bargaining Process; Sleeping Patents; Rest of the World; Terms of Trade; Distributive Justice; China; United States.
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Are All Technological Improvements Beneficial? Absolutely Not

1. Introduction

Economists attribute the idea of comparative advantage to David Ricardo (1817) and Henry Torrens (1815). Using a basic model that has certain restrictive assumptions, it can be shown that trade leads to higher levels of utility for all parties participating in international trade. This simplified model allows us to view the consequences of a country's economic policies as they function in an integrated economy. Economic interdependence among countries in today's world is not always symmetrical. Sometimes trade partners are on the verge of economic dependence, when costs are unequal between countries (Nayyar, 2006, p. 138).

The United States underwent a decline in net exports and manufacturing since China has entered the World Trade Organization in 2001. Between 2001 and September 2009, the United States lost 5.3 million jobs in the manufacturing sector, corresponding to nearly one-third of total employment. Some analysts directly attribute as much as 2.3 million U.S. jobs that were lost between 2001 and 2007 to the growth of U.S.'s trade deficits with China. [1] Meanwhile, China maintains a trade surplus; for example, May 2011 figures show a $25 billion trade surplus in non-seasonally adjusted goods alone (U.S. Census Bureau, 2011). As economies in the World recover from the last recession, exports become a key part of a country's welfare. If the U.S. wishes to sustain its position as an economic power as the world economy becomes more integrated, it needs to enact policies designed to continuously improve its competitiveness in several areas outlined below.

A study undertaken by the Economic Policy Center described the impact of Chinese imports on United States' trade deficit and job losses. Since China has joined the WTO, the

U.S's import growth has increased from 3.8 percentage points to 18.6% per year whereas its export growth has increased negligibly. While the Chinese annual growth rate of exports is approximately 18.84 percent, the corresponding value for the U.S. is less then 0.05 percent and is declining (see Figure 2). In 2008, U.S. imports from China exceeded exports by a ratio of nearly 5:1, an increase of $338 billion in imports versus $70 billion in exports in that year.[2] During this period, China has improved its technological capabilities by sustainably investing in research and technology.

In the same period, the United States' trade deficit has increased. The United States is lagging behind most other industrialized countries in improving its human resources. According to a report by the United States Cooperation and Development, while prior to 1970 United States had the highest graduation rate in the world, United States now ranks 18 out of 36 other industrialized countries. High school graduation rate is a key indicator for the performance of the economy and the skill level of its future labor force. Furthermore, while a high percentage of students who graduate high school do enroll in college, roughly only fifty percent graduate with a bachelor's degree from a four-year college.[3]

Moreover, studies by the Organization for Economic Cooperation and Development (OECD) in 2006 show that American students lagged in mathematics and the scientific abilities as compared with most other rich countries. The average science score of U.S. students lagged behind those in 16 of 30 countries, and in math United States was behind 23 other countries, and ahead of just four.[4]

In our current model, one assumes that there are two asymmetric countries, like the United States and China in the above discussion, that are capable of producing only two goods using only one factor of production, labor. This factor of production generates different productivity levels for each country. If one assumes that the goods being traded are complementary goods and that the utility extracted from each bundle is identical for each resident, then trade will be beneficial for both parties. In this augmented model, it can be demonstrated that under autarky, the country with fewer consumers is able to provide a higher standard of living. This is because the same quantities of both goods are distributed equally among fewer numbers of consumers. By opening the markets to international trade, both parties are able to gain. It can be demonstrated that the most beneficial scenario to all consumers in both countries occurs when each country specializes in one commodity. When each country fully utilizes its comparative advantage, consumers are able to achieve maximum utility through their global interaction.

This paper utilizes a simplified model in order to analyze the effects of unilateral sustainable technological improvements on the behavior and welfare of both trading parties. Samuelson (2004) demonstrated that the permanent long-run effects of technological improvements under globalization are not necessarily beneficial to all parties (see also, Gomory and Baumol. 2000; Samuelson, 1948, 1949, 1972a, 1972b, 1981). This issue is related to the concept of immiserizing growth, where the sustainable economic growth path could lead to a situation where a country being permanently worse off than before the growth (Bhagwati, 1958, 1968; Johnson, 1955, 1967) and outsourcing (Bhagwati, Panagariya, and Srinivasan, 2004). Choi (2001) and Choi and Beladi (2006) contributed to the literature by applying the concept of immiserizing growth to the Asian financial crisis. This concept is also related to immiserizing transfer (Chichilinsky, 1980, and Bhagwati, Brecher and Hatta, 1983).

This paper studies the conditions under which both countries benefit, only one country benefits, and neither country benefits from trade after one country experiences technological innovation. This innovation causes a sustainable increase of the production possibilities. The result of the last case, where neither country benefits, is particularly interesting and should be considered by both policymakers and legislators. Although the model is simple, it illustrates a scenario that would warrant greater apprehension of long-run effects of free trade.

The remainder of the paper is organized as follows. Section 2 presents the benchmark model. Section 3 extends the benchmark model in order to analyze the effects of a sustainable technological improvement in China on the welfare of the two countries. Section 4 provides a general discussion accompanied with some numerical examples. Section 5 supplements the general discussion of the last section by providing some simple numerical examples to demonstrate some unpleasant free trade arithmetic. Section 6 discusses the policy implications of the model. Section 7 concludes.

2. The benchmark model

To set the scene and simplify the introduction to the benchmark model, consider the following numerical example. The generalization of these examples is straightforward. Assume that there are two countries: the technologically more advanced part of the world (country A) and the technologically less advanced part of the world (country B), with 10 and 100 workers, respectively. In country A, two of the ten workers specialize in the production of Good X—each produces one unit of X. The other eight workers specialize in the production of Good Y—each produces one unit of Y. In country B, eighty workers specialize in Good X—each produces 0.1 unit of X, and twenty workers specialize in Good Y—each produces 0.1 unit Y. Note that this model can be considered to be postulating an economy with an initial fixed endowment of a vector of goods.

Under autarky, the production bundle of goods X and Y in country A is X = 2 and Y = 8 units. The production bundle in country B is X = 8 and Y = 2. Further assume that the utility functions of consumers, who are also workers, in both countries are identical and are of the full complement form, i.e.,

(1) $U_i = \text{Min}(X_i, Y_i)$

where U_i is the utility of consumer i, X_i, and Y_i are the quantities of Good X and Good Y consumed by individual *i*.

Note that using the same utility specification for both representative agents of the two countries is equivalent to assuming that the underlying preferences of all the consumers are identical. For the case of identical agents see for example, Yildireim (2007). This could have been the case if, for example, communication systems that influence the consumers in the technologically less advanced part of the world to abandon their innate tastes and imitate and adopt the preferences of the consumers in the technologically more advanced country. A possible extension with different preferences is, for example, if the consumers in country A have the aforementioned utility function and strive to be on the 45 degrees line (in Figure 1). Meanwhile, the consumers in country B have a utility function of, say, $U=(bX,Y)$, where b is a positive scalar different from 1, and the consumers try to be on a line with a slope different from 45 degrees. In this case, the resolution of the bargaining is in the area between the two lines. With equal bargaining power, the equilibrium would be a point on a line located at an equal distance from the preferred line of each country.

In this framework, production and consumption do not match. Therefore, one concludes that under autarky, country A produces two units of Good X and two units of Good Y, leaving six workers who specialize in the production of Good Y structurally unemployed. If the two goods are distributed equally to all potential workers, regardless of whether or not they are employed, $U_i^A = 0.2$ for each consumer. Thus, the aggregate utility of all 10 consumers, U^A, is equal to 2.

Similarly for country B, under autarky, twenty workers produce two units of Good X and an additional twenty workers produce two units of Good Y, leaving sixty workers unemployed. Following the same assumption with regard to the distribution of goods among consumers, the utility level of each consumer is equal to: $U_i^B = 0.02$. Point A (for Autarky) in Figure 1 shows the production and utility levels where the aggregate utility level of each country is equal to: $U^A = U^B = 2$, where U^B is the aggregate utility for all 100 consumers in country B.

What are the effects of a movement towards an increase in global economic integration where the two countries open up their international borders to free trade, trading with each other? In this case, globalization leads to full employment where all workers of country A are employed, as indicated by point U in Figure 1, and all workers of country B are at point C. The terms of trade will be 1:1. Thus, three units of X will be exchanged for three units of Y. The aggregate utility of each country now equals 5, which is illustrated in Figure 1 at point O, where U_0 is equal to 5. The after-trade aggregate bundles of goods for both countries are identical, i.e., $X^A = X^B = Y^A = Y^B = 5$, where the X's and Y's define the total consumption of the two commodities and the letters B and A stand for country B and country A, respectively.

The next section shows how improvements in the productivity of the laborers of country B affect the utility levels of the two countries.

3. Technological improvement in the rest of the world

Any technological improvement in country B changes the production of goods from the original point C to a point northeast of it, as shown in Figure 1. A technological change also affects the Terms of Trade (TOT). It is assumed that a (Nash) bargaining process is negotiated between the two countries and is used to determine the terms of trade, with each country possessing the same bargaining power. Under the assumption of equal bargaining power, the TOT is most likely determined by the straight line between point U and the new production point of country B, say C^i, where i = 1, 2 denotes sub-regions (1) and (2) in Figure 1. For equal bargaining power see for example the pioneering work by Nash (1950), see also Hedberg (2009) Ma, Liu, Li and Yan (2012) and the review by Gintis (2000). For the case of relative, rather than equal bargaining power, see for example, Heughebaert and Manigart (2012) or Seebens and Sauer (2007).

To better explain the underlying assumption of equal bargaining power, recall that the two entities have the same utility function and desire to consume equal quantities of X and Y. However, each entity differs in its initial “endowment” or productivities. Each entity tries to sell its excess-supplied commodity for the highest price while buying the excess-demand product for the lowest price. Since the assumption is that each country has the same bargaining power, the final TOT is the straight line that is connected to the original initial production point. This bilateral bargaining resolution leads to equilibrium where the two countries achieve a similar level of aggregate utility. Any other TOT may lead to different utility levels, where one entity achieves higher utility from trade. However, such a situation would indicate a stronger bargaining power by one party, whereas the two entities are assumed to have equal bargaining power.

The idea above is related to distributive justice and property, which emphasizes a *just process* for defining and enforcing property rights rather than a *just outcome* or end result in the distribution of wealth from the exchange of goods (Nozick, 1974). According to one version of this theory, any distribution of wealth is justly provided when it starts from a just initial allocation of resources and achieves the final outcome by voluntary exchange. The most powerful modern statement of this view is in Nozick (1974); see also Spindler (1976) Murnighan (1991) Shapiro (2011), Kamas and Preston (2012), Henschke, (2012) and Schwettmann, (2012).

Furthermore, based on the specific utility function of both entities, or countries, each strives to approach the 45-degree line, which ensures that equal amounts of X and Y are consumed. However, the export and import levels are determined by the country that is closest to the 45-degree line. This is because each country is constrained by the condition that it can neither export more than the other party is willing to import, nor import more than the other party is willing to export. The main concern is whether this last constraint may lead to changes in the TOT resulting in a situation where the welfare level does not increase for either country. It is also possible that only one of the two countries benefits; this country does not necessarily have to be the one that initiated the technological changes. This issue is investigated below.

To proceed, divide the area designating the possible location of country B's new production point -- area $S_{O'CO''}$ in Figure 1 -- into two mutually exclusive zones.

In zone 1, located at $S_{O'CD}$, country B's total utility is above the previous free-trade level of 5 utils. On the line CD in Figure 1 a new production point for country B exists (say C', not shown in the figure, since it can be anywhere to the northeast of the point C) after the technological improvement. A straight line that connects this new production point C' and the original point U, is intersected exactly at the midpoint by the 45-degree line originated from the point C towards the northeast. If the un-shown point C' lies exactly on the line CD, then actual and planned imports and exports of both countries are equal and both countries are better off. However, points northwest to the line CD represent the cases where import and export values are determined by country B. This is the case because the 45-degree line from the origin cuts the Terms of Trade line and the line UC' not at the mid point, but at a point closer to point C' than to point U.

4. A general discussion

The advantages of trade are most apparent when there is a misalignment of the production abilities and the consumption requirements of a given entity. Such dissonance is evident as long as the gap between production abilities and consumption needs is significant; and policy makers need to consider ways to bridge this gap. The following two approaches should be considered:

a) Alter the production structure in favor of consumption needs by focusing more resources on required consumption goods, both by training and by changing the factors of production towards the production of the desired items. This may turn out to be very costly.

b) Use given resources to produce outputs along the most efficient trajectory, while simultaneously utilizing the potential to trade with other entities, thereby acquiring the desired consumption goods in exchange for the exported goods. In this approach, the costs are the transaction costs of the trading process such as transportation costs, tariffs, physical barriers, etc.

A third solution—that of adjusting tastes and consumption towards the production availability of the internal entity is not considered, since we believe it to be prohibitively expensive to perform and hard to apply, in addition to being generally undesirable. One notes that since technological improvements in one part of the world changes the relative price of the two goods, they consequently cause movement of workers from one industry to the other.

Policy makers should examine the tradeoff between training costs and transportation costs when the advantages of each avenue are considered. In many cases, the latter approach, namely international trade between or among the parties, is the preferred solution. Thus, from 1870-1914 and during the second half of the twentieth century, most developed and developing countries revolutionized transport and communications technology to reduce costs (see Nayyar 2006, Hampe, 2003 and Hummels, 2012).

Assuming the existence of free trade between two parties, we may ask what happens to their benefit levels should unilateral technological changes occur. Does the dependency of the two countries on trade benefit them both? Does it benefit either one of them? Under what circumstances does international trade benefit a country?

We demonstrate here that whether such technological change occurs intentionally or unintentionally, the results are ambiguous—it may lead to a Pareto improvement for both parties, but it may also lead to a decrease in welfare of *at least* one of the parties. If this is the case, the next issue is what should be done to *overcome* any technological changes that could harm rather than improve the countries' benefits and the advantages of international trade.

Technological Improvement (TI) can be intentional—via training, direct innovation leading to better performance of inputs, etc.—but it is often unintentional—resulting from external changes which simply occur by nature. When TI occurs unilaterally, three factors must be considered in analyzing what kinds of improvements are bestowed upon the parties.

1. When the TI occurs and increases the gap between the new production abilities and the consumption requirements, the dependency of the country with the new TI on international trade increases. If so, it may then have weaker bargaining power in terms of trade (TOT).
2. When the TI leads to a detour of the production bundle relative to the other country where no TI occurs, since the export and import volumes are dictated by the smaller country, which does not have enough resources to support higher volume of trade, the TI may change the (volume-of-trade-wise) smaller country into the larger country, allowing it to now dictate the terms of trade as well as the volume of trade.
3. As a result of the above, TOT may be influenced by the TI on the one hand and by the consumption requirements as well as the political and/or negotiation power of the trading parties on the other.

These three effects may lead to several scenarios. The first scenario represents a TI of one country, which results in relatively higher production of the imported item, as well as some minor improvement in the production of the exported item. In this situation, both countries benefit from trade, but the country where the TI occurs benefits more from trade since the country dictates the volume of imports and exports and usually is in a better position to generate a favorable TOT. In the extreme, the "improved" country can dictate the TOT as well as export and import volumes, thereby garnishing all the gains from trade for itself, with none left over for its trading partner.

A second scenario represents the situation where the TI is biased towards the exported item, although a minor improvement also occurs in the imported item. In this case, the volumes of export and import are dictated by the rival country. Moreover, the dependency of the country that achieves TI on both the export and import item is larger. This weakens the bargaining power of the "improved" country in production terms and may result in adverse effects on its TOT. As such, the country that benefits from TI may "hide" the improvement or opt not to use it for the sake of improved TOT. Eventually, both parties can benefit, though not all available resources will necessarily be used.

The extreme TI case where only the export item benefits from the improvement is the most challenging scenario. In such a case, the production improvement of the country leads to the following results:

a) The other country dictates the volume of trade between the two countries.
b) The supply of the exported item of the country with TI is higher; thus, the relative price is lower while the opposite occurs with the import good. This leads to changes in TOT to the detriment of the country with TI.

As a result of the possibility of trade, volume reduction may occur, leading to either lower utilities to the improved country or no benefit to either party. In such a case, the country with TI will not utilize the production changes—i.e., Pareto improvement in production costs does not necessarily lead to Pareto improvement in consumption and welfare.

This situation is interesting because it shows that technological improvements may lead to the cessation of what was previously a mutually beneficial trade. This case thus shows some potentially unfavorable free trade scenarios, where a Pareto improvement in production does not lead to a Pareto improvement in consumption and utility. This may even lead to a reduction in international trade.

5. Some unpleasant free trade arithmetic

A few numerical examples strengthen the intuition presented in the last section. Suppose that country B improves the production of Good Y to five units and continues to produce 8 units of Good X (point *a* in Figure 1). The new Terms of Trade (TOT) curve will be the straight line connecting U and point *a*. Mathematically, this line satisfies:

> Y = Intercept – 0.5 X. At point U, Y = 8, and X = 2. Thus, 8 = Intercept - 0.5(2), which leads to Intercept = 9. Thus, the TOT equation is: Y = 9 – 0.5X. The 45-degree line implies Y = X, thus Y = 9 – 0.5 X = 9 – 0.5 X, leading to consumption of Y = X = 6 in country B.

Therefore, country B produces 8 units of Good X, 6 of which are consumed and 2 are exported, and imports 1 unit of Good Y in exchange for 2 units of Good X. Country B's consumption of Good Y is now 6 units; 5 units from domestic production and 1 unit of Y from imports. Hence, country B's utility now increases to 6 utils.

What will happen to country A in this case? Since the exports and imports of country A in this case are determined by country B, country A would export 1 unit of Y and import 2 units of Good X. This results in 7 units of Y and only 4 units of X for country A; two units of X come from domestic country A's production and two are imported from country B. Here, the welfare of country A decreases to 4 utils while that of country B increases to 6 utils. This example demonstrates the case where following the technological improvement, welfare of country B improves and the welfare of country A deteriorates.

What if, rather than having a new terms of trade as above, the terms of trade remains at 1. In this case, country B exports 1.5 units of Good X for an import of 1.5 units of Good Y. Consequently, the utility of country B equals 6.5 utils, whereas that of country A equals the minimum between 6.5 and 3.5. For instance, if the welfare level for country A is now only 3.5 utils, which is even worse than in the previous scenario where TOT was not equal to 1:1. This completes the case of *a,* shown in Figure 1, demonstrating that technological improvement in zone 1, or its border, leads to welfare improvement for country B and welfare deterioration for country A. This example contradicts the claim by Krugman and Obstfeld (2009) that in the Samuelson (2004) model, a technological progress by China, country B in this case, makes the United States, country A in this case, worse off (only) by eliminating trade between the two countries. This last example shows that this is not the case.

Consider another case, case *b* in Figure 1, where country B improves its technology and can now produce 5 units of Y and 11 units of X. The new TOT line will combine the point U with point *b* in Figure 1. This line satisfies: Y = Intercept – 0.333 X. Substituting the values for X and Y at point U, namely Y = 8, X = 2, implies Intercept = 8.667, so the TOT equation in this case is: Y = 8.667 – 0.333 X. Imposing the X = Y constraint for the specific utility function yields X = Y = 6.5 units.

Who will be able to reach this point of consumption? Is it country B or country A? Consider country B first. For country B to be able to consume Y = X = 6.5 and adhere to the terms of trade equal to 0.333, it must produce 11 units of X, export 4.5 units of them, and import in return 1.5 units of Y. In this way, country B consumes 6.5 units of Good X and 6.5 units of Good Y, thus improving its well-being. What about country A? Country A will export 1.5 units of Y and import 4.5 units of Good X. Thus, the welfare of country A improves as well to Y = X = 6.5.

What if country B is successful in imposing the original pre-improvement terms of trade of 1 to 1? Producing X = 11 and Y = 5, country B exports 3 units of X for 3 units of Y and thus increases its consumption of Y and X to Y = X = 8. Consequently, country B increases its welfare to 8 utils. On the other hand, country A's consumption remains at its original bundle of

Y = X = 5 without any change in its welfare level. Therefore, one concludes that along the line CD, the 45-degree line, country B will always improve its welfare, whereas country A may either improve or remain at the same level of welfare.

The third possible scenario is depicted as point *c* in Figure 1. Assume that country B produces 14 units of Good X, and 5 units of Good Y. The new TOT line satisfies:

Y = Intercept – 0.25 X. Substituting for X = 14 and Y = 5 yields: 5 = Intercept – 0.25(14), leading to: Y = 8.5 – 0.25 X. Imposing now the constraint Y = X, yields X = Y = 6.8 units.

Which country can consume these levels of Good X and Good Y? Country B would like to produce X = 14 and Y = 5, and export 14 – 6.8 = 7.2 units of X, which leaves country B with 6.8 units of Good X. In this case, country B imports 7.2*0.25 = 1.8 units of Good Y, in addition to the 5 units of Good Y that country B produces, leaving country B with 6.8 units of Good Y. What would country A do? Country A exports 1.8 units out of the 8 units of Good Y it produces, leaving it with Y equals to 6.2 units. In exchange, country A imports 7.2 units of Good X, in addition to the 2 units of X country A produces. However, country A benefits from only 4.2 units of imported Good X, and thus 7.2 – 4.2 = 3 units of imported Good X are not used. In any case, the two countries increase their utility levels as a result of country B's technological improvement. Country B increases its consumption from 5 to 6.8 utils, and country A increases from 5 to 6.2 utils. This example demonstrates a case where some of the technological improvement is not fully utilized, but both countries are still better off.

Another extreme possibility is where the Terms of Trade remains at 1:1 as in the original case. Country B would like to move from producing X = 14, Y = 5 to the point closest to the 45-degree line CE, namely X = 9.5, Y = 9.5, with 9.5 utils. In this case, country B exports 4.5 units of Good X and imports 4.5 units of Good Y. Country A, in the case of 1:1 TOT, exports 3 units of Good Y and imports 3 units of Good X. Thus, country A's welfare stays at 5 utils, whereas country B will move to the consumption of X = 11 and Y = 8, increasing its utility level to 8 utils. In this case, country B's welfare increases, but we have overcapacity in production, and 3 units of Good X are not consumed by either country. This completes the discussion of point *c* in Figure 1.

Another possible outcome is illustrated by point *d* in Figure 1. Assume that country B's technological improvements only affect the production of Good X. Specifically, the production capacity of X increases from X = 8 to X = 11, whereas the level of production of Good Y stays the same at Y = 2. In this case, Y = Intercept – 0.667X. Substituting X = 11, Y = 2, yields the TOT equation: Y = 9.337 – 0.667X. Equating Y = X yields the consumption bundle:
X = Y = 5.6 units.

If country A determines the trade voluntarily (see below for an additional discussion), it would export 8 – 5.6 = 2.4 units of Good Y to country B, and under a TOT of 0.667, would import 3.6 units of X. Thus, the consumption of country A is X = Y = 5.6 units and its utility equals 5.6 utils. What about country B's welfare? If country B exports 3.6 units of Good X, and imports only 2.4 units of Good Y, country B will be left with too many units of Good X, 11 – 3.6 = 7.4 units of Good X, but only 4.4 units of Good Y: 2.4 imported and 2 produced locally. Consequently, country B's welfare decreases to 4.4 utils. This example illustrates an extreme case where a sustainable technological improvement in country B hurts the people of country B!

One way for country B to avoid the above situation is to improve its terms of trade by permanently "concealing" its technological improvements or by not using the new technology, thus actually producing less of its potential export, Good X, causing the relative price of its exported good to increase (see the discussion of sleeping patents below).

Assume again an extreme case in which country B produces at point *d* in Figure 1. Specifically, country B produces X = 11 and Y = 2, and "imposes" the original TOT of 1:1. Accordingly, country B would like to move to X = Y = 6.5 units with final utility level of 6.5 utils. However, in this case, country A is willing to export only 3 units of Good Y and import 3 units of Good X, leaving country B with X = 8 and Y = 5 and its utility level at 5 utils is unchanged.

Consequently, this example illustrates a case where a technological improvement in country B improves neither its own welfare, nor the welfare of country A! Another possible course of action that country B may take is to conceal its new technologies and somehow force country A to export more of Good Y in exchange for more imports of Good X. This is possible under a bargaining framework as long as country A ends up with more than 5 utils. In this case, both countries are better off by moving towards point *d*.

Consider the last scenario, but assume that the TOT remains at 2:3 and country B is interested in importing at least 3 units Good Y in order to maintain its original utility level of 5 utils. In this case, country B exports 4.5 units of Good X. The utility level of country A also remains at 5 utils. Thus, in this case, both countries do not benefit from the technological improvement in country B. Therefore, if country B bargains in a way such that it will improve its TOT, country B will benefit and country A will be harmed.

As mentioned above, this situation is interesting because it shows that technological improvements may lead to a cessation of what was previously a mutually beneficial trade. This case thus shows some potentially unfavorable free trade scenarios, where a Pareto improvement in production does not lead to a Pareto improvement in consumption and utilities. This may lead to a sustainable reduction in the volume and benefit of international trade. Thus, in this case the blessing due to the technological improvements is converted to a sustainable curse!

Along the line connecting the points *b* and *d* in Figure 1, if one moves from point *d* towards point *b*, the welfare of country B increases for two reasons. One, it is less dependent on its imports of Good Y from country A and hence increases its welfare by domestically producing more of Good Y for its own consumption. Two, the change in TOT causes a relative increase in the price of the exported commodity from country B: Good X. Thus, for example, at point *e* in Figure 1, where Y = 3 and X = 11, the welfare of country B definitely increases.

In this region country A loses. However, country A in this zone does benefit from globalization and trade in comparison to autarky equilibrium. In this case, technological improvement by country B causes a reduction in the total utility level in country A to be less than 5, but greater than 2. Otherwise, country A will benefit from completely ceasing trade with country B and as a consequence, both parties lose.

In zone 2, located in slice $S_{DCO''}$, two scenarios can occur: either both countries benefit from a technological improvement in country A, or only country B benefits. In this area, country A reaches the 45-degree line on the new trade line, but country B cannot reach it since the volume of trade, the exports and import "required" by country B, is larger than the volume that country A is willing to trade.

Another scenario can be that a technological improvement in country B leads to a situation in which, along the trade line, country A benefits whereas country B reaches a point below the indifference curve that denotes a level of 5 utils, its pre-technological improvement utility level. Under these circumstances, country B would be better off hiding or not revealing its technological improvement and hence would prefer to trade under the pre-innovation regime.

This phenomenon is similar to individuals who prefer not to disclose their over qualification while searching for jobs. A possible outcome is that under some assumptions, country B utilizes the innovation domestically but hides the true TOT. In this case, country A benefits less from trade, whereas country B has the choice of either utilizing the technological improvement or deciding to postpone the implementation of the improved technology.

The paper provides an explanation why sometime countries temporarily delay the introduction of innovation. This case is analogous to the concept of sleeping patents discussed in the industrial organization literature (Kutsoati and Zabojnik, 2005, Mattos, 2007, and Leung and Kwok, 2011,

6. Policy implications

On the basis of the above model, one can see the implications for today's United States. The first thing that one can take into account is the issue of the investment in human capital and in vocational educations of American students. A study in 2004 by the Program for International Student Assessment by the Organization for Economic Cooperation and Development, administered a test in 29 OECD nations and 10 others that included practical math applications. The study reports that "The nation's 15-year-olds, American 10th graders, ranked 24th out of 29 industrialized nations, behind South Korea, Japan and most of Europe. U.S. students' scores were comparable to those in Poland, Hungary and Spain." U.S. Secretary of Education Rod Paige called the results "a blinking warning light" that show the need to reform U.S. high schools.[5] The Washington Post[6] published a study in 2003, conducted by the American Institutes for Research (AIR) that helped to dismantle a widely held belief that "U.S. students do well in mathematics in grade school but decline precipitously in high school," (see Table 1). The study, funded by the U.S Department of Education, found that U.S. students in 4th and 8th grade perform consistently below most of their peers around the world and continue that trend into high school. Alan Ginsburg of the U.S. Department of Education, who helped coauthor the study, suggested that these studies shed light onto the weakness of U.S. mathematics instruction as early as elementary school.

Many analysts are concerned that too few U.S. students will be prepared to serve in the next generation of engineers, scientists and even physicians.[7] Allowing this trend to persist will severely undermine the competitiveness of the United States, especially in technology-related fields. This paper demonstrates the possible sustainable consequences to the welfare of the United States if it does not implement effective measures towards ensuring that its next generation of human capital is highly skilled and able to compete with the rest of the world.

Allocating more resources towards improving United States' education sector would offer a high return on investment in human capital. Improving the current education system and enhancing job-training programs may even provide short-term benefits in helping to combat the U.S.'s current unemployment level and the dismal projections of slow job growth for the next years. Jeffrey Sachs writing for the Financial Times, suggests that a massive expansion of education and training would help remedy the current unemployment crises "by shrinking the number of people who are searching for work… [and by] increasing spending in the economy through education outlays." The United States must strengthen its commitment towards ensuring its sustainable dominance in the next generation of technology and science.

Another illustration of the United States lagging behind is in the area of broadband and telecommunications infrastructure. The Federal Communication Commission (FCC) recently released a report, titled the National Broadband Plan[8] that stressed the importance of maintaining a competitive edge in modern broadband communications infrastructure[9] and faulted the market for failing to bring the power and promise of broadband to all Americans. According to the FCC, United States ranks only 12-th in broadband penetration and 15-th in average broadband speed. Moreover, the FCC cites a study that ranked the U.S. 6-th in the world in innovative competitiveness, and 40-th out of the 40 countries in "the rate of change in innovative capacity."[10] A study by the Information Technology and Innovation Foundation, an independent research group, recently released a study describing that "all of the 39 other countries and regions studied have made faster progress toward the new knowledge-based innovation economy in recent years than the United States. As indicated by the change score, the United States has made the least progress of the 40 nations/regions in improvement in international competitiveness and innovation capacity over the last decade." For a country that has been the sustainable pioneer of new research and technology for decades, this study is disturbing.[11]

The Chief Operating Officer (COO) of International Business Machines Corporation (IBM), Mr. Palmisano, warns of United States' excessive reliance on traditional forms of communication and infrastructure, such as bridges and roads which it deemed "the infrastructure of an analog era" and its failure to focus on "building the communications of tomorrow."[12] In just three years, the world's internet-providers traffic is estimated to reach more than half a zettabyte, which is equivalent to one trillion gigabytes. There is also expected to be not only vastly more data, but data that will be far richer and require much greater bandwidth. He cautions that, without pervasive broadband, the U.S. will not be prepared for a new world that is increasingly built on the fusion of the physical and the digital.

Bearing in mind that manufacturing and exports no longer play the prominent role they once have and that services now comprise more than three-quarters of the U.S. economy, the

United States must maintain a sustainable competitive edge in an increasingly digital era of services. Many countries, such as Spain, have already been using modern digital technology to revolutionize the way they deliver health care through enhancing information access at the point of care. As Palmisano stresses, "whether in health care, finance, engineering or entertainment, services will be increasingly digital, delivered over broadband." The Chinese government is undertaking bold steps in increasing their broadband capabilities. Thus, the U.S. needs to continuously update its communications systems.

To ensure that it remains ahead in an increasingly digital era, the United States must permanently expand public investments in information technology in areas such as health care, energy systems, transportation, government, and education. It also need to ensure that the appropriate regulatory frameworks are in place so that growth is promoted in these areas rather than inhibited. The Information Technology and Innovation Foundation, an independent research group, suggests, in a report highlighting the importance of digital technology, that enacting more favorable immigration quotas towards high skill immigrants may be a "source of many new ideas and innovations."[13] Other policy recommendations include, expanding funding for university research, and other kinds of mechanisms that help foster commercialization of research. Thus, boosting support for local economic development, entrepreneurship and workforce training. The purpose is to create market-based incentives for greater innovation and technology upgrades, such as offering tax incentives for research institutions and businesses that invest in information technology.

The United States needs to ensure that it stays ahead in the clean energy sector despite not being a part of the Kyoto Protocol (see, for example, Aldy and Stavins 2010). Clean tech is becoming more important across the World, and the U.S. needs to be competitive in this area in order to maintain its leadership role in the world economy. The U.S. Administration recently affirmed that, "The country that leads in clean energy and energy efficiency today will lead the global economy tomorrow" (*The Economist*, May 1, 2008). This source cites a lack of entrepreneurial talent and stagnation in the development of new technologies as major impediments to present Clean-tech investment. Unfortunately, this has been compounded by the recent stalling credit markets that have slowed aggregate venture capital investment, including investment in the Clean-tech sector. *The Economist* (Nov. 6, 2008) suggests that the current recession will only result in a short depression in Clean-tech investment and that many orders of wind turbines and solar panels have been placed on hold until the national economy recuperates. Hence, the drop in clean energy investment is anticipated to be largely temporary.

Countries that pollute heavily such as The United Arab Emirates and China are investing hundreds of millions of dollars in environmentally friendly projects. The need for clean technologies to replace processes based on limited fossil fuel energy will still be present after the economic crisis subsides. The Economist (Nov. 6, 2008) claims that major areas of high social return are currently blocked by the lack of U.S.'s clear policies. The conversion to a low-carbon economy would create American jobs in the short run, a more productive economy in the medium run, and U.S. technological leadership in the longer run. Despite promises by the U.S Administration for a green recovery – one where the jobs would come through a massive expansion of low-carbon energy, the Administration has not taken the initiative to emerge as the forerunners for green energy. Unless something is done, as Jeffrey Sachs warns, "we will spend our time digging out of the next consumer bust and buying our technology from China" (Financial Times, November 11, 2009). Thus, this paper illustrates the consequences of the United States not investing in innovative emerging industries that heavily use new research and development, which may lead to unpleasant consequences to its citizens, abandoning its leadership role.

While this paper discusses the ramifications of a technological advancement in China, the reality is that only recently has China been investing in innovative behavior. According to Lipsey, Carlaw and Bekar (2005), during most of the 19th and 20th centuries, China lacked a competitive edge in technology and knowledge development. They claim that in the West (Western Europe and the United States), three changes were adding to the second industrial revolution. These were lower mortality rates in the mid to late 19th century, higher fertility rates from 1880 until the beginning of World War I, and increased investment in human capital. These changes allowed workers to improve their skills, earn higher wages, and thus increase their standard of living (Lipsey, Carlaw and Bekar, 2005).

Despite the perceived benefits from innovation, many times innovating societies are slow to actually innovate (Lipsey, Carlaw and Bekar 2005). There are several factors that can interfere with innovation in a growing or industrialized country. Inventions and new technologies take uncertainty and sometimes high initial costs without knowing the actual results ahead of time. This means that inventors and those financing them are sometimes hesitant because of the chance of failure. Additionally, some innovators may feel as though they will not reap sufficient rewards from their innovations or government institutions actually stand to lose from private ventures and innovators, so they actually restrict innovation and the spread of ideas (Lipsey, Carlaw and Bekar 2005).

In this respect policies such as the ones suggested by Phelps (1998, 2010) are worth serious considerations. For example, creating a National Bank of Innovation — a state-sponsored network of merchant banks that invest in and lend to innovative projects. Other policies may include exempting start-ups from corporate income tax for a time, improving corporate governance by indexing executives' compensation to long-term sustainable performance rather than one-year profits, and by linking fund managers' pay to skill in picking stocks, not in marketing their funds (Phelps, 2010). These recommendations should by applied not only as a temporary short-term urgent measures as a response to crises, but as a consistent sustainable long term strategy to remain a leader in a continuously more integrated global world. This is the direction that the analysis of this paper suggests.

Although it is not the main focus of this paper, the results above have also implications of an interrelated important issue of migration by laborers from the technologically less-advanced, low income countries. This legal and illegal labor migration is currently being heavily debated both in the United States, Europe and Australia. Technological improvement in any part of the world can affect the flow of migrant labor.

7. Conclusion

This paper examines some unpleasant free trade arithmetic as the result of unilateral technological improvement. In particular, in an integrated economy, it is possible for unilateral technological improvements to be harmful to the party that did not undergo such innovation. Moreover, it is also possible for the innovating country to be harmed as a result of the changes in the Terms of Trade brought about by its own advancement. This thought experiment offers explanations for the question of why some object to free trade. Furthermore, this paper explicitly shows that unilateral technological improvements neither guarantee an increase in the welfare of the innovative country, nor promise enhancement in the standard of living of its trading partner.

In fact, unilateral technological improvement can yield some unpleasant free trade arithmetic that can potentially lead to a sustainable reduction in the volume of free trade.

In the late nineteenth and early twenties centuries, globalization and international trade did not lead to rapid growth across the globe. Indeed, the industrialized countries prospered disproportionally compared to the small emerging economies at the time. This period was characterized by a widening gap in per-capita income and living standards among countries (Nayyar, 2006). The effects of globalization within the last fifty years have been accrued under the assumption that quantitative changes will lead to qualitative changes and substantial improvements in the global economy. However, the impact of globalization has been exaggerated. The growth of economic variables seems substantial and sustainable in absolute terms, but in relative terms from year to year, it is less so. More should also be done to look at the limitations to globalization, such as restrictions on migration and a disproportionate control of the economy by the services sector (Michie, 2003).

Admittedly, this model uses very specific and unique assumptions with fixed-proportion production and consumption functions. However, this is done for simplicity purposes. The message can be broadened to apply to many integrated economic situations without devaluating the conclusions of this study. Furthermore, if one renames the two trading partners, say “China” and the “Rest of The World", and if we assume that currently the labor force in the agricultural sector of China is inefficiently employed, i.e., structural unemployment in the Chinese agricultural sector, then the assumption of fixed proportion–Leontief's (1951) idea—is applicable.

The model developed in this paper has profound policy implications. Policymakers and legislators throughout the World need to be aware that although technological improvements increase productivity for a country, it does not necessitate that there will be gains in consumption and utility for the innovative country. In some circumstances, the country's trading partner becomes the primary recipient of the benefits of the new technology.

Under autarky, an initial scenario with high unemployment was constructed, based on some extreme assumptions of different fixed ratios in production and consumption. As a result of opening the market to free trade, it is shown that one may completely eliminate unemployment in both countries. Under such circumstances, it seems as if opening the market to international trade will improve the welfare of the two countries because now everyone is employed. However, this paper shows that even in this case, it is not always certain that a free trade regime will lead to a higher standard of living. This is an interesting case because one can "export" unemployment, and it still may not increase the welfare of both countries.

China has increasingly used part of their huge trade surplus to invest in new technologies and better prepare their human resources to the new millennium. Other countries are far ahead of the United States as far as k-12 educations and investment in new energy resources. Furthermore, many countries are investing in new technologies. As is seen through our simplified example, such investments and policies are necessary in order to stay economically competitive. Thus, it seems that the U.S. should direct its sustainable efforts to improving its labor force and its decaying infrastructure in order to sustain its position as a leading economy. Unsustainable trade deficit by the U.S. is a problem with its roots firmly in current U.S. policies, and it should not be attributed to other countries.

The paper highlights the need for each country to enact policies that maintain the sustainability of global economic growth. We show that the innovative country is not always the one that will gain from introducing the innovations. Thus, the paper advocates policies that enhance continuous sustainable cooperation among countries in order to better utilize the innovations to guarantee that such investment in research and development will pay off to all parties involved.

This paper shows, using a simple model, that wasteful innovations may result in a loss-loss situation where no country experiences an increase in welfare. If some countries introduce innovations that result in harmful effects on other countries, it may cause the adversely affected countries to retaliate by imposing impediments to international trade. In a globalized and integrated World economy, such policies can only harm the countries involved. Thus, it is in both countries' best interests to encourage sustainable coordination between policies in order to better their own citizens, as well as the World's aggregate welfare.

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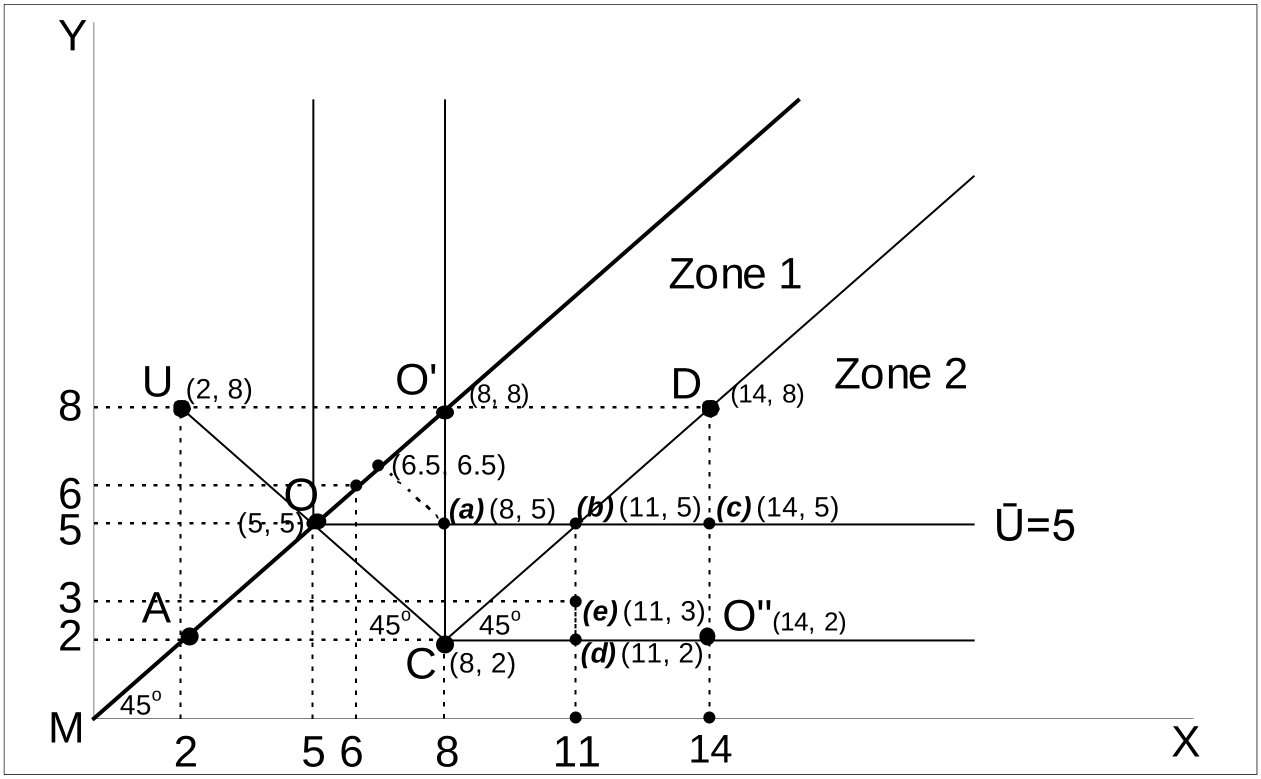
Figure 1: Production and consumption bundles in the two countries



The line CD is the border line between zone 1 and zone 2. The line CD is the geometric line that along it, the other straight line connecting the point U to the point, say C' is crossed by the 45° line labeled MO'. The point C' is not shown in the figure, since its location can be anywhere northeast of the region bordered by the points O'CO'. For the case of fixed proportion production functions for Goods X and Y, and a fixed proportion utility function, the terms of trade are determined by the line connecting point U with the, again not plotted, point C'.

Figure 2: Annual change of U.S. exports to the world

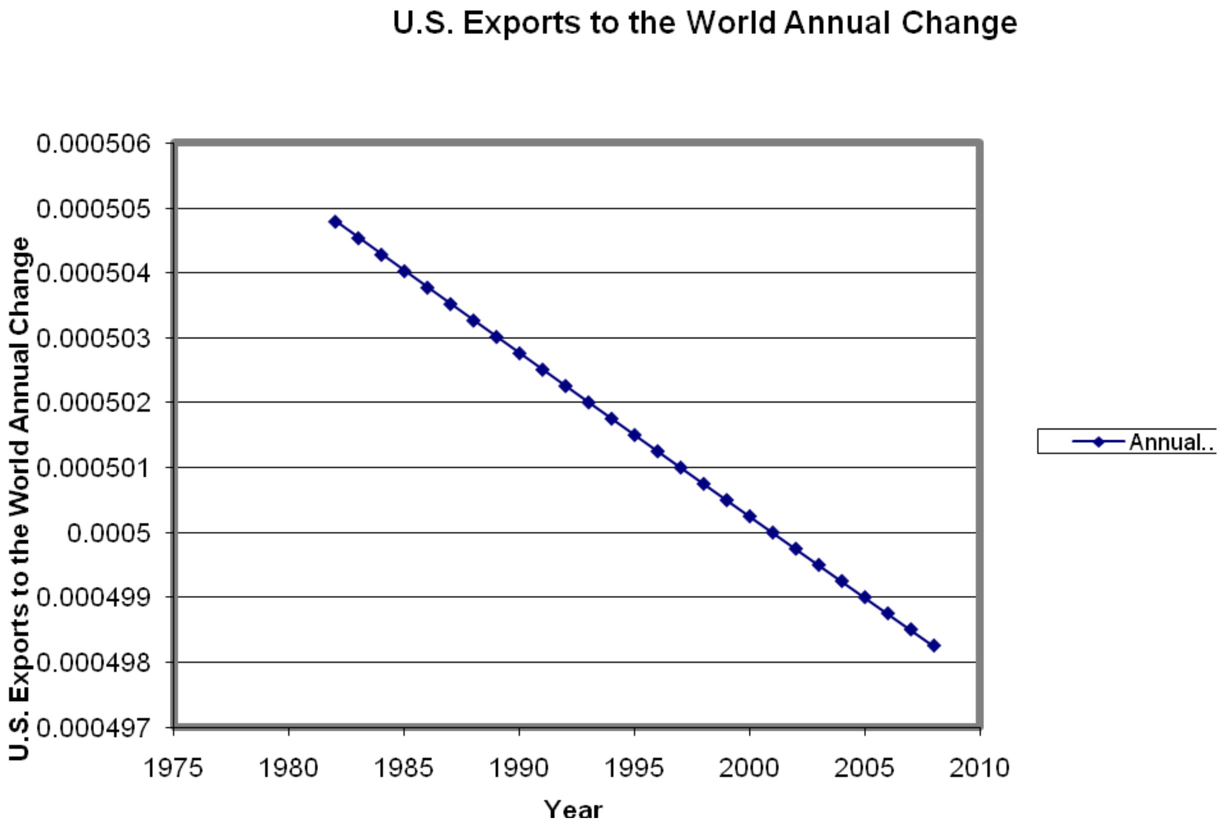


Table 1: Rankings1 of 12 Countries Participating on the 2003 International Mathematics Assessments: TIMSS Grades 4 and 8, and PIS

	New Analysis			Previous Analyses		
Country	**Common Set of 12 Countries**			**Full set of 24**	**Full set of 45**	**Full set of 40**
	TIMSS	**TIMSS**	**PISA**	**TIMSS**	**TIMSS**	**PISA**
Hong Kong	1	1	1	2	3	1
Japan	2	2	3	3	5	6
Belgium	3	3	4	5	6	8
Netherlands	4	4	2	6	7	4
Latvia	5	6	9	7	11	27
Hungary	7	5	8	10	9	25
Russia	6	6	11	8	11	29
Australia	10	8	5	15	14	11
United States	**8**	**9**	**9**	**11**	**15**	**27**
New Zealand	11	10	6	16	20	12
Norway	12	12	7	20	27	22
Italy	9	11	12	14	22	31

1 Country rankings for common set of 12 countries are from highest score (equals 1) to lowest score (equals 12). Country rankings from previous analyses are from highest score (equals 1) to lowest score (equals 24 for TIMSS Grade 4, 45 for TIMSS Grade 8, and 40 for PISA).

http://www.air.org/news/documents/TIMSS_PISA%20math%20study.pdf

'Trends in International Mathematical and Science Study' published in the Washington Post.

Eight graders from the United States rank below students in many Asian countries when it comes to Science and Math, according to The Trends in International Mathematics and Science Study.

TIMSS rankings show that the US students rank 11th in Science and 9th in Math.

Notes

[1] See: http://epi.3cdn.net/97e3cf1bed3c89a4b0_jem6bn0u6.pdf
[2] See: http://epi.3cdn.net/97e3cf1bed3c89a4b0_jem6bn0u6.pdf
[3] http://www.upi.com/Top_News/2008/11/19/US-slipping-in-education-rankings/UPI-90221227104776/
[4] http://www.washingtonpost.com/wp-dyn/content/article/2007/12/04/AR2007120400730.html
[5] http://www.usatoday.com/educate/mathscience/article-math2.htm
[6] http://www.air.org/news/documents/Release200511math.htm
[7] http://www.washingtonpost.com/wp-dyn/content/article/2007/12/04/AR2007120400730.html
[8] http://www.fcc.gov/cgb/broadband.html
[9] http://www.washingtonpost.com/wp-dyn/content/article/2010/03/15/AR2010031503785.html
[10] http://www.fcc.gov/Daily_Releases/Daily_Business/2010/db0224/DOC-296490A1.pdf
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[12] http://online.wsj.com/article/SB10001424052748704804204575069102256344456.html?mod=WSJ_Opinion_LEFTTopOpinio
[13] http://www.itif.org/files/2009-atlantic-century.pdf