In: Trends in International Trade Issues
Eds.: Robert V. Weeks, pp.1-
ISBN 1-60021-029-5

Chapter 3

A NEW FOUNDATION OF ECONOMIC THEORY AND ITS APPLICATION TO TRADE ANALYSIS

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ABSTRACT

In the last two decades, a lot of models have been developed about the new trade theory. The work by Avinash Dixit and Joseph Stiglitz (1977) is often credited as the crucial innovation that made the new trade theory possible. In Dixit and Stiglitz (1977) and later works, models of production costs involve fixed costs and variable costs, which makes economy of scale easy to understand. In these models, fixed costs and variable costs are independent constants. Although it is intuitively clear that a production system with higher fixed cost generally have lower variable costs, a lack of analytical theories make it difficult to implement this intuition. In this chapter, we propose an economic theory based on the foundation of thermodynamics. From this new foundation, we develop an analytical theory to obtain a formula that explicitly representing the relation of fixed costs, variable costs and the uncertainty of the environment, which is the core concern in most economic decisions. It enables us to make detailed comparison of returns of systems with different fixed costs in different kinds of markets. It offers a clear understanding on why countries at different stages of development will adopt different trade policies. This understanding is highly consistent with the historical patterns that all latecomers that emerged into industrial powers, such as USA, adopted protectionist policies in the period of takeoff and shifted to free trade policy to access larger market for their products after their industries became highly competitive. This theory also shows that patterns in trade are intrinsically linked to migration restriction and explains why the current trade and migration system is not sustainable over the long term.

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INTRODUCTION

Since the publication of *What Is Life* and other works more than half century ago, there is a consensus in the scientific community that life processes in general and human activities in particular are thermodynamic processes. However, the theory of thermodynamics only has limited impact on economic theory and social sciences. (Georgescu-Roegen, 1971) This is largely due to the lack of an analytical theory of economics based on the foundation of thermodynamics. In this chapter, we will develop such a theory and show how it provides much more realistic and intuitive understanding of trade problems than the general equilibrium theory, the analytical foundation of neoclassical economic that was inspired by Newtonian mechanics.

Human activities are predominantly economic activities, which are chiefly regulated by the exchange value of different economic commodities. The current value theory does not provide a measurable quantity to value. (Debreu, 1959) Since all human activities represent extraction and transformation of low entropy from the environment, it is natural to relate economic value to low entropy. From the properties that the value of commodities should satisfy, we derive that the only mathematical formula to represent value, as a function of scarcity, is the entropy function. This is parallel to that the only mathematical formula to represent information, as a function of probability, is the entropy function. (Shannon, 1948) The entropy theory of value offers a unified understanding of physical entropy, information and economic value. (Chen, 2002a) It provides a quantitative framework to understand how different factors affect the value of a commodity. The influence on value by factors such as scarcity and the number of producers of a commodity can be naturally understood from the entropy formula of value. It provides some new insights about the trade policies.

For example, traditional trade policy often regards trade quota to be harmful to consumers by raising the cost of imported goods. (Romer, 1994) From the entropy theory of value, value of a product is inversely related to number of producers. The quota system forces the transfer of production technology from leading export countries to other countries. Ultimately, the diffusion of technology and the increase of the number of producers will intensify competition, which will reduce the value of the imported goods. This will result in a net welfare gain to the import countries over the long term, instead of the welfare loss suggested in most literature.

Living systems, as non-equilibrium systems, need to extract low entropy from the environment to compensate for continuous dissipation. (Schrodinger, 1944; Prigogine, 1980) This process can be represented mathematically by geometric Brownian motion. From the entropy law, the thermodynamic diffusion of an organic or economic system is spontaneous. The extraction of low entropy from the environment, however, depends on specific biological or institutional structures that incur fixed or maintenance costs. Higher fixed cost systems generally have lower variable costs. In this chapter, we derive the thermodynamic equation that variable cost of a production system should satisfy and solve it to derive an analytic formula that explicitly represents the relation among fixed costs, variable costs, uncertainty of the environment and the duration of a production system, which is the core concern in most economic decisions. (Chen, 2002b)

In the last two decades, tremendous amount of papers are written about the new trade theory. The work by Avinash Dixit and Joseph Stiglitz (1977) is often credited as the crucial

innovation that made the new trade theory possible. (Fujita, Krugman, Venerables 1999) In Dixit and Stiglitz (1977) and later works, models of production costs involve fixed costs and variable costs, which makes economy of scale easy to understand. In these models, fixed costs and variable costs are independent constants. Although it is intuitively clear that a production system with higher fixed cost generally have lower variable costs, a lack of analytical theories make it difficult to implement this intuition. The analytical theory developed in this chapter enables us to make detailed comparison of returns of systems with different fixed costs in different kinds of markets.

From this analytical theory, it can be derived that high fixed cost systems, with lower variable costs, are more competitive and benefit more from increasing returns. At the same time, higher fixed cost system needs larger market size to break even. So higher fixed cost systems prefer a large and open market. Low fixed cost systems, with higher variable costs, are less competitive and benefit less from increasing returns. At the same time, lower fixed cost system needs small market size to break even. So lower fixed cost system prefers a protected market. Historically, all latecomers that emerged into industrial powers, such as USA, adopted protectionist policies in the period of takeoff. After these industries become highly competitive, government policies gradually shifted to free trade to access larger market for their products. (Bairoch, 1993)

The theory developed in this chapter offers a unified understanding of life processes. This universality helps relate trade policies to problems in other disciplines. For example, a common argument against infant industry policy is that once government provides support to a new industry, it is difficult to decide when this industry to become independent. It is also difficult for parents to decide when their children to become independent. But should we expose infants to "market competition" immediately after they are born because of this difficulty? The fact that we can not time the "optimal" moment to let children go independent does not mean they should not be supported at all. For the same reason, the difficulties involved in supporting new industries should not discredit infant industry policies completely.

The rest of the chapter is structured as follows. Section I introduces the entropy theory of value. Section II introduces the analytical dynamic theory of production and competition. Section III applies the theory to understand trade policies. Section IV discusses the long term consequences of current trade and migration policies and concludes.

THE ENTRPOPY THEORY OF VALUE

"The problem of value must always hold the pivotal position, as the chief tool of analysis in any pure theory that works with a rational schema." (Schumpeter, 1954, p. 588) However, after several hundred years of devoted works by some of the greatest economists, "today value theory remains in a highly unsettled state." (Mirowski, 1989, p. 147)

Since all human activities represent extraction and transformation of low entropy from the environment, it is natural to relate economic value to low entropy. (Schrodinger, 1944; Prigogine, 1980) Indeed "there have been sporadic suggestions that all economic values can be reduced to a common denominator of low entropy." (Georgescu-Roegen, 1971, p. 283) However, some conceptual difficulties prevented the development of an entropy theory of value.

Georgescu-Roegen thought that linking economic value to low entropy would not be of much help to economist because "he would only be saddled with a new and wholly idle task ---- to explain why these coefficients differ from the corresponding price ratios." (Georgescu-Roegen, 1971, p. 283) To this argument we may compare the works of Shannon and Wiener on information theory. Both defined information as the reduction of entropy. (Shannon, 1948; Wiener, 1948) However, Shannon further apply the mathematical definition to obtain some results that are of fundamental importance in information theory, while recognizing that the mathematical definition of information is not identical to the meaning of information in our daily use. As a result, Shannon established information theory as a science. In this paper, we show that while economic value is not identical to physical entropy, the entropy theory of value, an analytical theory based on fundamental physical laws, enables us to obtain some results that greatly clarify the meaning of economic value and are highly consistent with our intuitive understanding. Among other things, it offers a clear understanding why economic value is different from physical entropy.

How is the entropy theory of value related to the existing economic theories of value? Neoclassical economics, the current mainstream economic theory, was developed around 1870 by Jevons, Walras and others. Walras (1954), the chief architect of neoclassical economics, argued that value is a function of scarcity. From the properties that the value of commodities should satisfy, it can be derived that the only mathematical formula to represent value, as a function of scarcity, is the entropy function. This is parallel to that the only mathematical formula to represent information, as a function of probability, is the entropy function. (Shannon, 1948) Thus the entropy theory of value is the analytical representation of Walras' vision.

Value is a function of scarcity. Scarcity can be defined as a probability measure P in a certain probability space. It is generally agreed that value of products satisfies the following properties:

a. The value of two products should be higher than the value of each of them.
b. If two products are independent, that is, if the two products are not substitutes or partial substitutes of each other, then the total value of the two products will the sum of two products.
c. The value of any product is non-negative.

The only mathematical functions that satisfy all the above properties are of the form

$$V(P) = -\log_b P \qquad (1)$$

where b is a positive constant. (Applebaum, 1996)

In general, suppose a service or product, X, can perform different tasks, with probability of $p_1, p_2, \ldots p_n$, Then the value of this product is the average of the value of each task. That is

$$V(X) = \sum_{i=1}^{n} p_i(-\log_b p_i) \qquad (2)$$

Therefore, value, just as information, in its general form can be defined as entropy. In information theory, the base of the logarithm function is usually chosen to be two because there are two choices of code in information transmission, namely, 0 and 1. In this entropy theory of value, the base b can be understood as the number of choice of producers. In the following we will discuss the properties of value as entropy.

Scarcity and Value

Figure 1 is a graph of (1). From (1), value is an increasing function of scarcity. That is why diamond worth more than water. In the extreme abundance, i.e., when P=1, -log P =0 and the value of the commodity is equal to zero, even if that commodity is very useful. For example, food is essential for survival. Most countries subsidize food production in various ways to guarantee the abundance of food, which causes its low economic value. This shows that economic value and social value are two distinct concepts.

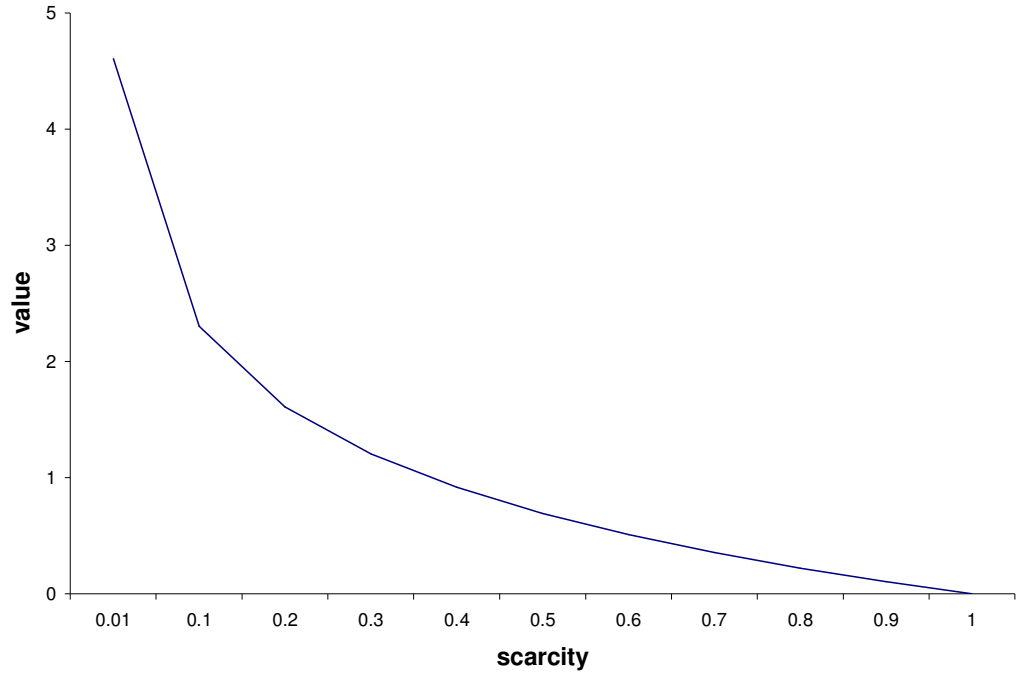

Figure 1: Value and scarcity

Value and the Number of Producers

From (1), value is inversely related to the number of producers. Figure 2 displays the relation of value and number of producers. When the number of producers is small, the value of a product is high. That's why monopoly products are valued highly. If the base becomes

one, i.e., absolute monopoly without substitution, value becomes infinity. This happens at some religious cults where only the spiritual leaders hold the key to heaven. In these types of organizations, the leaders often enjoy infinite power over their followers. The number of providers of some economic goods depends on many factors. In the following, we only give a brief discussion about institutional structures.

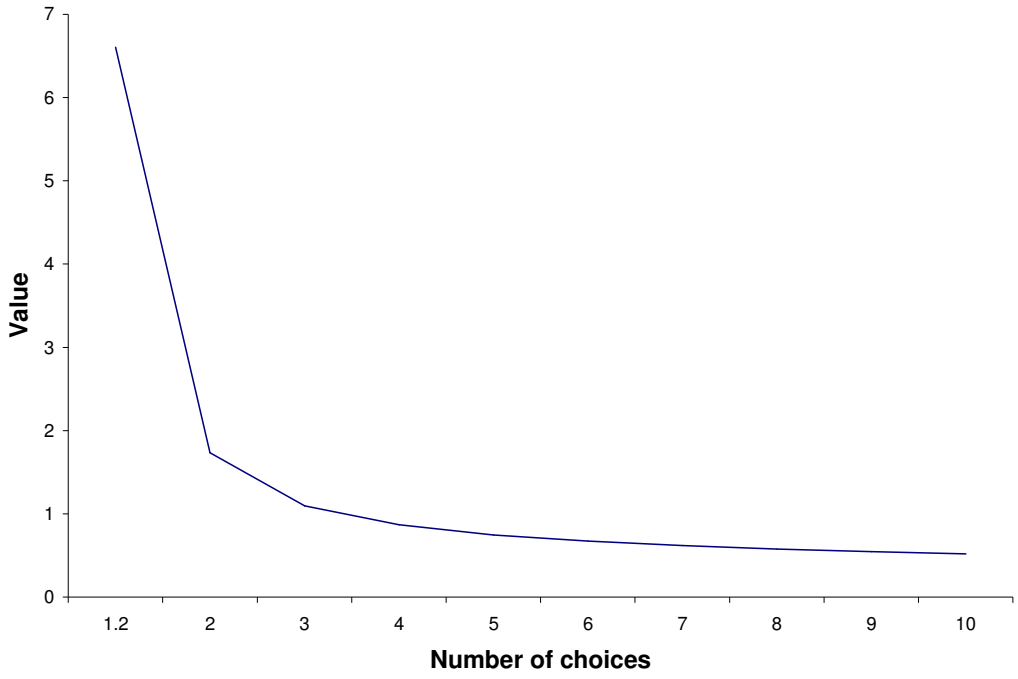

Figure 2: Value and the number of producers

The anti-trust regulations aim at preventing the price fixing from existing providers of a service or product and lower barriers to potential entry. Both measures, by increasing the number of choices, reduce the value of products, and hence the cost to consumers. The value of a product is lower in a more competitive market.

The patent right and commercial secrets legislation, on the other hand, by granting monopolies and discourage knowledge diffusion, maintains the high value of new products and successful firms. The value supporting legislation encourages innovation and reward good management. The balance between fostering competition and protecting innovation is always a delicate one. (Arrow, 1999)

Substitutability and Value

Many products and services are not identical but can substitute each other to a certain degree. The value of a single product can be defined as its entropy (2). The total value of two products can be defined as their joint entropy

$$V(X,Y) = -\sum_{j=1}^{n}\sum_{k=1}^{m} p_{jk} \log(p_{jk}) \quad (3)$$

while the individual value of X and Y can be defined as

$$V(X) = -\sum_{j=1}^{n} p_j \log p_j$$

$$V(Y) = -\sum_{k=1}^{m} q_k \log q_k$$

It can be proved that (Shannon, 1948)

$$V(X,Y) \le V(X) + V(Y) \quad (4)$$

The equality holds only when X and Y are independent, i.e., X and Y are not substitute or partial substitute to each other. This means that substitutability reduces the value of a product. The purpose of brand name management and advertisement of a product is to make a product special and to reduce the substitutability of it, which increases the value of that product.

Market size and Product Value

Suppose the potential market size of a product is M. The percentage of people who already have the product is P. Then the unit value of the product is

$$-\log P \quad (5)$$

Since the number of people who have bought the product is MP, The total value of the product is

$$MP(-\log P) \quad (6)$$

From (6), the value of a product is higher with a larger market size. Figure 3 is the graph of unit value and total value of a product with respect to its abundance. From Figure 3, we can explore the relation between the value of a product and the stages of its development. When a product is new and scarce, the unit value is high. Its total value is low. As the production increases, the total value will increase as the unit value decreases. When the production quantity is over a certain level, however, the total value of a product will start to decrease as well. Intuitively, this is easy to understand. The market values of manufacturers of mature products are generally low, although the production processes are very efficient. This observation shows that efficiency is not equivalent to value.

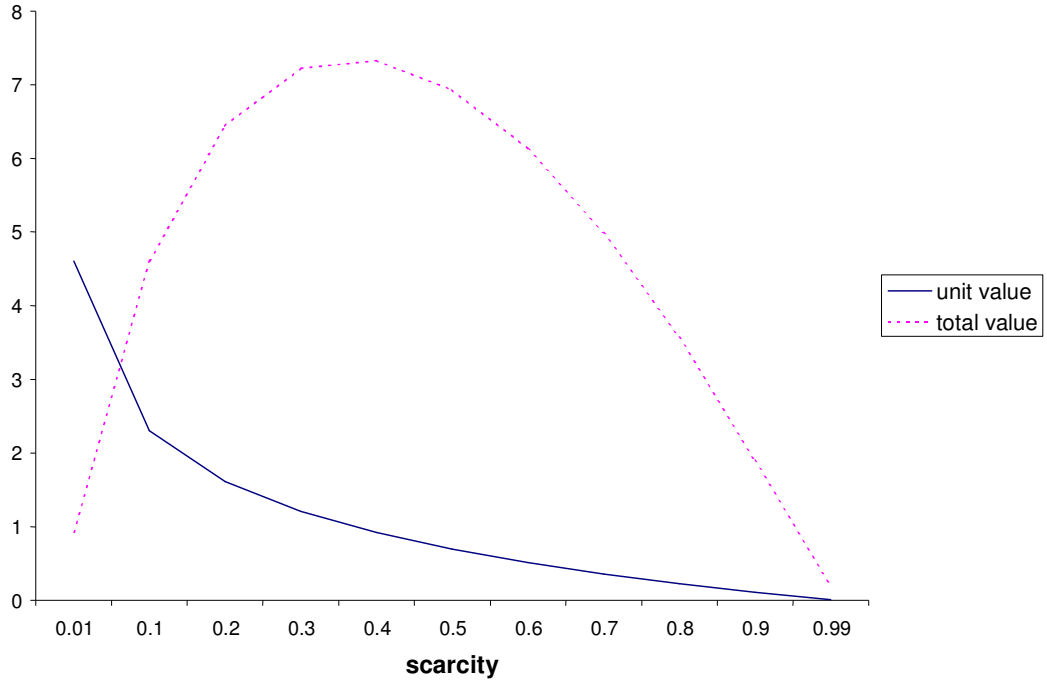

Figure 3: The unit value and total value of a product with respect to scarcity

The above discussion shows that the implications of identifying value with the reduction of entropy are highly consistent with our intuitive understanding of economic value. It should be noted that in economic processes, a final product embodies many different kind of scarcities: labor, raw materials and capital. A detailed analysis of the value of a particular product will be much more involved.

It is well known that economic values of commodities are highly correlated with the level of physical entropy. However, they are not identical for several reasons. In the following, we will discuss two: One from the perspective of information theory and another from the institutional structures that regulate scarcity.

First, the entropy level we perceive of a commodity is different from its original entropy level. The amount of information one can receive, R, is equal to the amount of information sent minus the average rate of conditional entropy.

$$R = H(x) - H_y(x) \qquad (7)$$

The conditional entropy Hy(x) is called the equivocation, which measures the average ambiguity of the received signal. (Shannon, 1948) Equivocation is determined by the statistical correlation between the receiver and the sender. The lower the correlation between the sender and the receivers are, the higher the level of equivocation will be. In the extreme case when x and y are independent, Hy(x) = H(x) and R = 0. So the information y can receive from x is zero when x and y are independent, regardless how much information x is sending out. Equivocation arises because receivers don't have the complete background knowledge of signals. For example, gold, a scarce commodity, is highly valuable. Another commodity

could be as scarce as gold. But unlike shining and stable gold, it is very difficult to identify. Most people will not put effort to gain the knowledge to identify this commodity because the cost outweighs potential benefit. Thus it registers less attention and is valued less by human beings.

Second, scarcity of a commodity depends on the institutional structures that enforce property right. For example, the value of an invention is influenced by how long and how broad patent protection is granted. The value of a patent is higher in a system where patents are valid for twenty years than one for ten years. From (4), substitutability reduces the value of a product. If patent protection is defined broader, the value of an invention is higher. Economic value, as a function of scarcity, is to a great extent regulated by institutional structures. Among all the institutional measures that regulate scarcity, the most important regulation is the immigration laws that regulate the scarcity of labor forces, which makes the persistent wage differential across regions possible.

The above discussion concludes the theory of value, which is essentially a static theory. In the next section we will discuss the dynamic theory of production and competition.

BASIC THEORY OF PRODUCTION AND COMPETITION

All biological systems, human or non-human, need to extract low entropy from the environment to compensate continuous dissipation. Suppose S is the amount of low entropy of a biological system, r, the rate of extracting low entropy from the environment and σ, the rate of diffusion of the low entropy into the environment. Similarly in an economic system, S represents economic value, r, the rate of return and σ, the rate of diffusion. Then the process of S can be represented by the lognormal process

$$\frac{dS}{S} = rdt + \sigma dz\,. \tag{8}$$

Solving (8) for S yields

$$S = S_0 e^{(r-\frac{1}{2}\sigma^2)t+\sigma z_t}\,, \tag{9}$$

in which S_0 is the initial value of S. From (9), the average growth rate of S is

$$r-\frac{1}{2}\sigma^2. \tag{10}$$

This shows that economic growth depends on the expansion of natural resources and the reduction of diffusion of low entropy. The utilization of energy and machinery represents the increase of r. Legal codes, cultures and the advance of information technology represents the decrease of σ. They play different roles in determining the rate of return.

A production system, whether a state, a region or a firm, involves fixed cost, K, and variable cost, C, which are functions of the S, the value of the product. If the discount rate is

q, from Feymann-Kac formula, (Øksendal 1998) the variable cost, as a function of S, satisfies the following equation

$$\frac{\partial C}{\partial t} = rS\frac{\partial C}{\partial S} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 C}{\partial S^2} - qC \tag{11}$$

To solve for variable cost from this equation, we need to determine the initial condition that the variable cost has to satisfy at time zero. When the duration of a system is infinitesimal small, the project has only enough time to produce one piece of product. If the fixed cost is lower than the value of the product, the variable cost should be the difference between the value of the product and the fixed cost to avoid arbitrage opportunity. If the fixed cost is higher than the value of the product, there should be no extra variable cost needed for this product. Mathematically, the initial condition for variable cost is the following

$$C(S,0) = \max(S - K, 0) \tag{12}$$

where S is the value of the product and K is the fixed cost. Suppose the fixed assets will be depreciated in T years. Solving the equation (11) with the initial condition (12) yields the following solution

$$C = Se^{(r-q)T}N(d_1) - Ke^{-qT}N(d_2) \tag{13}$$

where

$$d_1 = \frac{\ln(S/K) + (r + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln(S/K) + (r - \sigma^2/2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

The function $N(x)$ is the cumulative probability distribution function for a standardized normal random variable. When the discount rate is equal to the rate of return, formula (13) becomes

$$C = SN(d_1) - Ke^{-rT}N(d_2) \tag{14}$$

It takes the same form as the well-known Black-Scholes (1973) formula for European call options. This analytic formula explicitly represents the relation among fixed costs, variable costs, and uncertainty of the environment, which is the core concern in most economic decisions.

The variable cost of a production mode is an increasing function of volatility. As fixed costs are increased, variable costs, calculated from (14), decrease rapidly in a low volatility environment and decreases slowly in a high volatility environment. (Figure 4)

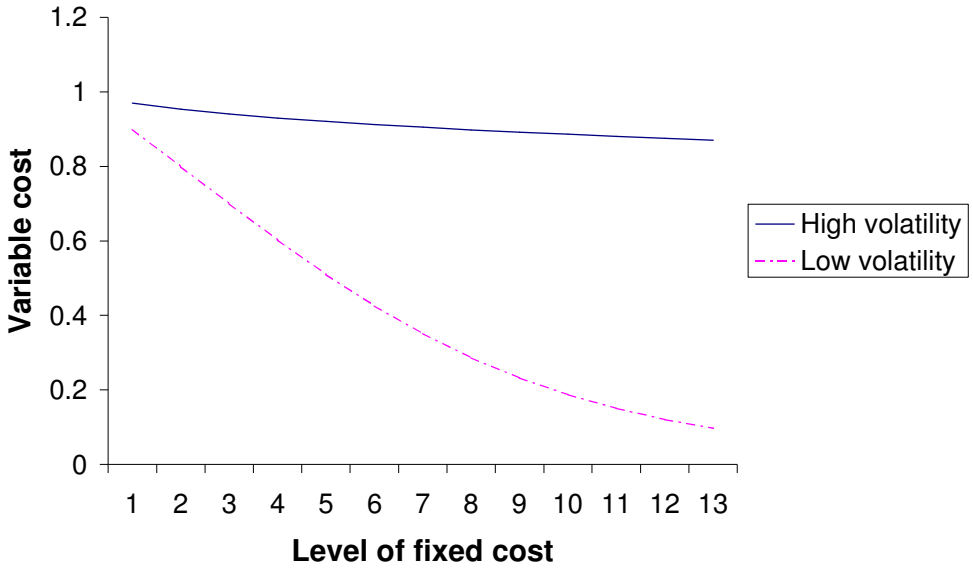

Figure 4: Volatility and variable cost

Suppose K is the fixed cost of a production system and $C(K, \sigma)$ is the variable cost. Assume the duration of the production system is one unit of time. A system with the fixed cost of K, which makes Q units of output, has total cost of

$$C(K,\sigma)Q + K. \tag{15}$$

The total value of the products is SQ and the return that this producer earns is

$$\ln\left(\frac{SQ}{C(K,\sigma)Q + K}\right) \tag{16}$$

Figure 5 is the graphic representation of (16) for different levels of fixed costs.

High fixed cost systems, with lower variable costs, are more competitive and benefit more from increasing returns. At the same time, from Figure 5, higher fixed cost system needs larger market size to break even. So higher fixed cost systems prefer a large and open market. Low fixed cost systems, with higher variable costs, are less competitive and benefit less from increasing returns. At the same time, from Figure 5, lower fixed cost system needs small market size to break even. So lower fixed cost system prefers a protected market.

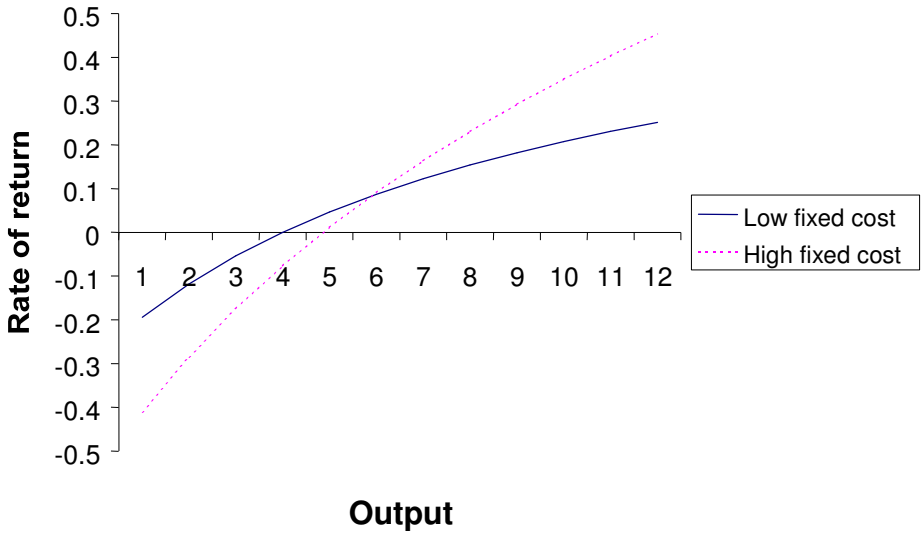

Figure 5: Output and return with different levels of fixed costs

APPLICATIONS TO ECONOMIC GEOGRAPHY AND TRADE THEORY

In the last two decades, tremendous amount of papers are written about the new trade theory. The work by Avinash Dixit and Joseph Stiglitz (1977) is often credited as the crucial innovation that made the new trade theory possible. (Fujita, Krugman, Venerables 1999) In Dixit and Stiglitz (1977) and later works, models of production costs involve fixed costs and variable costs, which makes economy of scale easy to understand. In these models, fixed costs and variable costs are independent constants. Although it is intuitively clear that a production system with higher fixed cost generally have lower variable costs, a lack of analytical theories make it difficult to implement this intuition. The analytical theory developed here enables us to make detailed comparison of returns of systems with different fixed costs in different kinds of markets.

Adam Smith noted that the division of labor is determined by the size of the market. A system of finer division of labor has higher fixed cost because the production involves more people and more coordination. This system is also of lower variable cost because of the efficiency gain. From Figure 5, a finer division of labor, which has higher fixed cost, is more profitable when the market size is large. As division of labor becomes finer, final products often are the results of corporation among more people or firms. Since physical closeness facilitate communication and transportation, firms often agglomerate into clusters, such as Silicon Valley. Because of increasing return to scale, the industrial or commercial clusters tend to self reinforcing. With economy development and technology progress, more and more people move to cities, the hubs of knowledge, information and transportation.

The clustering of firms and distribution systems cause the clustering of human population. Free movement ensures that real wages are roughly equal across regions. Globally, the efficient processing of goods and information in the developed countries creates huge demand in the labor market. From the value theory, value, including the value of labor,

is a function of scarcity. To maintain high real wages, developed countries adopt strict migration control to limit the supply of labor. To a country as a whole, labor cost can be better understood as fixed cost. Developed countries, with high labor costs, generally promote free trade to increase the size of the market of their products. Less developed countries or "latecomers", being of lower fixed assets and higher variable costs, are less competitive. At the same time, from Figure 5, lower fixed cost systems do not need large market size to sustain themselves. So they prefer protective trade policies. Countries may also want to protect the growth of most promising industries, the industries with large market size, high set up costs and low marginal costs. A look at the historical development of trade policies of England and America will illustrate how countries at different stages of development will adopt different trade policies.

In early nineteenth century, England was the dominant force in manufacturing. Ricardo, an English economist, wrote the following:

> Under a system of perfectly free commerce, each country naturally devotes its capital and labor to such employments as are most beneficial to each. This pursuit of individual advantage is admirably connected with the universal good of the whole. By stimulating industry, by rewarding ingenuity, and by using most efficaciously the peculiar powers bestowed by nature, it distributes labor most effectively and most economically: while, by increasing the general mass of production, it diffuses general benefit, and binds together, by one common tie of interest and intercourse, the universal society of nations throughout the civilized world. It is in this principle which determines that wine shall be made in France and Portugal, that corn shall be grown in America and Poland, and that hardware and other goods shall be manufactured in England.

If United States adopted this comparative advantage theory, today US would still be mainly a corn growing country. While Ricardo saw it optimal that corn should be grown in America and manufacturing shall be in England, Alexander Hamilton, an American lived roughly at the same time as Ricardo, apparently had different opinions. Since his argument is as relevant today as was two centuries ago, we will quote him in detail.

> Experience teaches, that men are often so much governed by what they are accustomed to see and practice, that the simplest and most obvious improvements, in the most ordinary occupations, are adopted with hesitation, reluctance, and by slow graduations. The spontaneous transition to new pursuits, in a community long habituated to different ones, may be expected to be attended with proportionally greater difficulty. When former occupations ceased to yield a profit adequate to the subsistence of their followers, or when there was an absolute deficiency of employment in them, owing to the superabundance of hands, changes would ensure; but these changes would be likely to be more tardy than might consist with the interest either of individuals or of the Society. In many cases they would not happen, while a bare support could be insured by an adherence to ancient courses; though a resort to a more profitable employment might be practicable. To produce the desirable changes as early as may be expedient, may therefore require the incitement and patronage of government.
>
> The apprehension of failing in new attempts is perhaps a more serious impediment. There are dispositions apt to be attracted by the mere novelty of an undertaking – but these are not always the best calculated to give it success. To this, it is of importance that the confidence of cautious sagacious capitalists, both citizens and foreigners, should be excited. And to inspire this description of persons with confidence, it is essential, that they should be made to see in

> any project, which is new, and for that reason alone, if, for no other, precarious, the prospect of such a degree of countenance and support from government, as may be capable of overcoming the obstacles, inseparable from first experiments.
>
> The superiority antecedently enjoyed by nations, who have preoccupied and perfected a branch of industry, continues a more formidable obstacle, than either of those, which have been mentioned, to the introduction of the same branch into a country in which it did not before exist. To maintain between the recent establishment of one country and the long matured establishments of another country, a competition upon equal terms, both as to quality and price, is in most cases impracticable. The disparity, in the one or in the other, or in both, must necessarily be so considerable as to forbid a successful rivalship, without the extraordinary aid and protection of government.

Because of protectionist policy of US government, US manufacturing industry was able to establish. After US industry became highly competitive, the government policy gradually shifted to free trade to access larger market for domestic products.

Why the establishment of a new industry often needs the support from the government? It often requires substantial fixed cost investment in a new industry before it becomes viable. From Figure 4 and 5, high fixed cost investment is highly sensitive to market uncertainty and require large market size to breakeven. Government support, by lowering uncertainty and guaranteeing market share, increases the chance of success of a new industry.

All superpowers of the time advocate free trade, while poor countries prefer protectionist policies. So it is easy to link free trade with prosperity, and protection with poverty. But historically, all latecomers that emerge into industrial powers, such as USA, Japan, Germany, adopted protectionist policies in the period of takeoff. Those countries that were forced into free trade all sink into poverty over time. (Bairoch, 1993)

Why domestic competition is generally encouraged while international competition needs finer policy? The fundamental difference is labor mobility. Labor mobility is often considered the most important factor in economic efficiency. There are always winners and losers in market competition. Firms which lose in competition often have to close down. Workers who work in these firms often develop specialized skills that are highly valued in particular contexts. When labors are free to move, which is the case in domestic markets, these workers will move to more successful companies or regions with more job opportunities. This mobility tends to equalize the real wages across regions. In international labor markets where migration is strictly controlled, these skilled workers often don't have the opportunity to utilize their skills and become low income unskilled labors. As a result, some countries with more competitive industries gradually deindustrialize other countries that do not or cannot adopt protective trade policies. (Krugman and Venerables 1995) Historical data show that the gap of living standard between third world countries and developed countries has been increasing over time. (Bairoch 1993)

Trading is often explained by comparative advantages, which are often classified as labor intensive and capital intensive. Some developed countries are densely populated. In general, all metropolitan areas in developed countries are densely populated. Yet no one call these areas as labor intensive. So labor intensive really is a euphemism of low wage. Since capital is highly mobile, there is no real comparative advantage being "capital intensive". Capital intensive really means high wage. While low wage is an advantage to employers, it is never an advantage, comparative or absolute, to labors, who are always the majority in any country. In general, the countries that unconditionally adopt free trade policies all sink into poverty

over time. (Bairoch 1993) Mexico under NAFTA offers a new example. "There has been a steady erosion in the purchasing power of both minimum and average wages in the 1990s. … The dramatic fall in real wages explains why labor income as a percentage of GDP fell from levels over 40% in the early 1980s to 30.9% in 1994, and a mere 18.7% in 2000." (Ramirez 2003, 881)

Ricardo used an example of two countries trading to illustrate the idea of comparative advantage. Most of the later literature essentially follows the same argument. In the following, we will use a similar example that incorporates more precise understanding on product value and production process.

In the real world, a small number of countries specialize in high tech industries, which are of high R&D costs and low marginal costs. Most other countries specialize in low tech industries, which are mature industries with low R&D costs and high marginal costs. To model this pattern, we assume there are twelve countries of equal size in the world. There are no intrinsic differences among them. Two countries specialize in high fixed cost, low variable cost industry while the other ten countries specialize in low fixed cost, high variable cost industry. Assume the fixed cost and variable cost for the first industry is 5 and 50% of the product value respectively. The fixed cost and variable cost for the second industry is 0.5 and 80% of the product value respectively. One can think of the first product as the high tech product, while the second one as low tech product. Assume the market size is 1000 and market saturation for both products is 80%. From the value theory, the unit value of the first product is

$$-\log_2 0.8 = 0.32$$

while the unit value of the second one is

$$-\log_{10} 0.8 = 0.09$$

Suppose the outputs of each product are equally shared by producing countries, then the output value of the first product for each of the producing countries is

$$\frac{1}{2}(1000 * 0.8 * (-\log_2 0.8)) = 128.8$$

The return on the first product to each of the two producing countries is therefore

$$\ln(\frac{128.8}{5 + 0.5 * 128.8}) = 0.61$$

With similar calculation, the return on the second product to each of the ten producing countries is 15%, which is much lower than 61% of the first product.

A highly profitable industry from one country inevitably attracts competition from many other countries. Since the production of first product requires high fixed cost, it is difficult for countries specializing in low tech products to gain foothold in high tech industries. However,

if one country manages to do so, with the help of government policy or other reasons, the following is the new rate of return for producing two products.

Since the first product now has three producers, the unit value of the product is now

$$-\log_3 0.8 = 0.20$$

while the unit value of the second product, which now has nine producers, becomes

$$-\log_9 0.8 = 0.10$$

Using the same methodology, it can be calculated that the return on the first product becomes 52% while the return on the second product becomes 16%.

These results are easy to understand intuitively. The calculations show that the country that is able to move into the production of high tech industry earns a higher rate of return. Overall, the rate of return on high tech industry is lowered because new entry increase competition and reduce product value, while the rate of return on low tech industry was increased because of the reduction of competition.

The above analysis assumes that each country takes the same share in a particular industry. The distribution in the real world, however, is very uneven. High fixed cost industries, because of their low marginal costs, usually consolidate into very few places. The rise of new production centers, which, by necessity, are often more efficient than the original production centers, is often accompanied by the decline of the original production centers. For example, the rise of Japanese auto industry was a devastation to US auto industry. Anyone who visited Detroit in early 1990s would agree with this statement. How would early comers respond an industry becomes less competitive than other countries? If an industry is of low fixed cost and low marginal profit, the government in general intervenes less because of the low market value. If an industry is of high fixed cost, low marginal cost and of large market size, the government will often actively intervene because huge value is at stake. For example, US government put an import quota on Japanese cars to save the domestic car industry, which is of great value to national economy. Suppose US government did not intervene in the car industry. The US auto companies, with little time to adjust, would all collapse. All the physical assets and human assets built over many decades will be lost permanently. Most people associated with the car industry, who are highly paid employees, will become unskilled people. In fact, most of them probably could not even be employed as unskilled workers because they have been used to work only in “decent” environments. In the language of trade theory, the new equilibrium will be at very low level. Other related industries, such as service industry that depend on the highly paid car industry, will collapse as well. While US consumers may be able to buy cheaper cars, the country will lose all the value of the fixed assets in the auto industry that are built up over many decades. Since the value of the auto industry is high, the total loss is much larger than the gain from lower prices for domestic consumers. So, while developed countries support free trade in principle, they will actively intervene to protect key industries.

In the following, we will discuss some specific trade policies, such as quota system and tariff. An extensive literature surrounds the issue of cost and benefit of import quota and

tariffs. (Romer, 1994) The identification of value as entropy sheds new light on this issue. The quota system forces the transfer of production technology from leading export countries to other countries. Ultimately, the diffusion of technology and the increase of the number of producers will intensify competition. From (1), the increase the base will reduce the value of the imported goods. This will result in a net welfare gain to the import countries over the long term, instead of the welfare loss suggested in most literature.

However, the quota systems, by restricting the scale of production and reduce the value of the products, do increase the cost and reduce the profit to the original leading exporters. By limiting the size of the market, it will also discourage exporters to adopt higher fixed cost production systems and expensive innovation.

Next we will discuss tariff policy. In natural resource industries, production output is often regulated to maintain sustainability. From the value theory, product value is a function of scarcity. Tariff policy can often significantly influence output quantity and hence product value, especially when a certain commodity has one big producer and one big consumer. Suppose country C is a big producer of softwood lumber while country A is a big consumer of softwood lumber. From value theory, the value of lumber market is represented by $-VP\ln P$, where P is the proportion of lumber that is on the market. Assume V, the total volume of the forest, is 10000. For country A as a consumer, it will be beneficial to design a trade policy to increase the production of lumber since it will reduce the value of lumber.

Suppose the cost structure of the lumber industry is the following. The total fixed cost in lumber production in country C is 100. The marginal cost is 60% of product value. So the total value of the lumber products is $-VP\ln P$ and the total cost of production is $100+0.6*V*P*(-\ln P)$. Suppose every year, 2% of the all lumber is harvested. The profit on lumber production is

$$\begin{aligned}
&-VP\ln P-(100+0.6*(-VP\ln P))\\
&=-10000*0.02*\ln(0.02)-(100+0.6*(-10000*0.02*\ln(0.02)))\\
&=213
\end{aligned}$$

Recently, country A imposes a 27.5% import duty on lumber from country C. If the volume of production remains at the same level, the profit for lumber production would be

$$\begin{aligned}
&-VP\ln P*(1-0.275)-(100+0.6*(-VP\ln P))\\
&=-10000*0.02*\ln(0.02)*(1-0.275)-(100+0.6*(-10000*0.02*\ln(0.02)))\\
&=-2
\end{aligned}$$

which means that the lumber industry will lose money. Production of lumber has to be increased to avoid loss. If the production level is increased to P = 3%, the profit for the lumber industry will becomes

$$\begin{aligned}
&-VP\ln P*(1-0.275)-(100+0.6*(-VP\ln P))\\
&=-10000*0.03*\ln(0.03)-(100+0.6*(-10000*0.03*\ln(0.03)))\\
&=31.5
\end{aligned}$$

As the production is increased from 2% of the total reserve to 3%, the unit value of lumber is decreased from –ln(0.02)= 3.9 to –ln(0.03) = 3.5. So Country A collect 27.5% tariff on lumber import and enjoy lower price on lumber, while profit level of country C's lumber industry is greatly reduced. Although lumber producers will attempt to recoup part of the tariff costs by raising prices, it is generally difficult because of the increased supply. This shows that tariff policy can have great welfare effects to relevant countries.

LONG TERM CONSEQUENCES OF CURRENT TRADE AND MIGRATION POLICIES

Because of migration control, technology advantage in developed countries is translated into high labor income. At the same time, the high labor cost makes it difficult for developed countries to compete with low wage countries in mature industries. Because of knowledge diffusion, developed countries have to keep innovate to maintain their lead, which requires long and continuous education for most people at tremendous cost. Figure 5 shows the rate of return as a function of output for systems with different levels of fixed costs. For a higher fixed cost system, it takes a higher output before the return becomes positive. The return curve for the higher fixed cost system is also steeper. This means that high level investment in education, which is largely a fixed cost, is riskier and when the investment is successful, the return is higher. To ensure the investment to be successful, more resources are put on each child. That is why the regions where high level of education is required for good jobs usually have lower fertility rates. The long time education and training forces many potential parents to delay the reproduction and to reduce the number of children to be born. As competition intensifies, the fertility rates in most developed countries have dropped far below the replacement rate. This raises big concerns about the sustainability of the social system in developed countries.

Peripheral regions, on the other hand, can't compete with the developed countries except in mature industries. The opening up of trade creates consistent labor surplus in developing countries, which depress wages. Because of the difficulties in learning the latest knowledge for most people in developing countries, the return on education is low there. As a result, most people adopt a low fixed cost strategy and choose not to spend lengthy years in school. From Figure 5, it takes less effort to make a positive return in a low fixed cost environment. Empirical investigation showed that it is of great benefit for a poor family to have more children because each child offers new potential for the future of the family. (Bledsoe 1994)Although low income families are often advised to reduce their fertility rates, "neither evidence nor analysis has yet disproved the notion that the poor in poor countries know, at least in a rough manner, what is in their best interest." (Dasgupta 1995, 1899) The increased population further worsens the labor surplus problem and depresses the labor income, which makes "the growth is the best contraceptive" impossible to realize. Poverty and high population growth feeds on each other to form a positive feedback.

This analytical theory confirms the empirical regularity that the levels of cost of living and fertility feed on each other to form a positive feedback. As any system in positive

feedback, the current social system will not stabilize and set into an equilibrium state without a fundamental change of policies.

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