Protectionism, Turbulence, and Growth

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Abstract

This paper discusses today's growing protectionism using a framework for thinking about economic growth, trade, and capital flows drawn from the natural sciences. In this framework economic activity is viewed as transformations of energy—both current solar energy and vintage solar energy, stored in the form of natural resources, human capital, physical capital and technology—driven by the laws of thermodynamics. The paper explains why efficient global capital markets and high-speed communications networks accelerate global economic growth. It then uses recent developments in nonequilibrium thermodynamics (NET) to outline the link between rapid growth, accelerating trade and cross-country capital flows, and turbulence, in the form of protectionism. Finally, it discusses an approach for mitigating the harmful impact of unavoidable turbulence and protectionism on the global economy.

Introduction

At Nobelist Robert Mundell's recent Santa Columba Conference, the assembled group of specialists in international finance agreed on two points: 1) the global economy today is growing as fast as at any time in history, and 2) the greatest risk to sustained global growth is rising protectionism, especially in the United States. This paper addresses the forces driving protectionism and looks at ways to blunt their harmful effects on growth.

Global growth this year is likely to exceed 5%, the highest rate in nearly a half-century. Developing Asia—the epicenter of the world's economic growth explosion—will grow at nearly twice that rate, led by the spectacular reform-driven performances of China and India.

Advances in information technology and communications networks have driven recent increases in global growth through three primary channels. First, they have made it possible for people to view each other's lives in real time for the first time in history. This has exposed gaping income and wealth differentials across nations, and motivated people in low-income countries to demand pro-growth policy reforms from their governments.

Second, communications technology has made it easier, faster, and cheaper to move resources around the globe to take advantage of price and return differentials. Labor, capital, and technology now move at the speed of light through fiber-optics networks low cost, which has accelerated growth in emerging economies.

Third, advances in global capital markets since the early 1980s have reduced the cost of moving capital and, therefore, the minimum return-differential threshold for triggering capital redeployment.[1] Policy reforms, including the recent WTO-mandated opening of China's capital markets, have made capital still easier to move. The result has been broader and deeper capital markets, faster adjustment and higher economic growth.

These changes, however, have not only increased global growth, profits, and stock market values; they have also created growing economic and political conflicts within and among nations. These conflicts are manifesting themselves as rising protectionist pressures.[2]

In two recent papers (Rutledge 2007a, 2007b), I have outlined a new framework for economic activity based on the laws of thermodynamics, which describes the energy transfers that drive all activity on earth, including economic activity. In this framework, entrepreneurs respond to energy gradients (price and return differences) by employing both *current*

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[1] Aarhenius Behavior, states that the rate of a chemical reaction (almost always) increases with rising temperature. (Atkins (1991), pp. 104-105.) The rule known as Aarhenius Behavior—first proposed by the Dutch Chemist Jacobus van't Hoff (1884) and interpreted by Svante Aarhenius in1889—states that reaction rate is an exponential function of temperature, or Rate = $k_0e^{-Ta/T}$. In this expression, T_a represents the reaction-specific *activation temperature*—the threshold below which no reaction will occur. Ludwig Boltzmann derived an expression for the proportion of collisions between molecules in a reaction that occur with at least the *activation energy* E_a (the threshold below which no reaction will occur) as $e^{-Ea/kT}$, where k, known as Boltzmann's constant, is a fundamental constant of nature. Our economic interpretation of E_a is the minimum price difference, in microeconomics, or minimum return on capital difference, in capital markets, required to trigger a profitable arbitrage transaction. E_a represents the friction, transportation costs, or transactions costs of engaging in markets. Reducing E_a increases adjustment speed for a given price gradient.

[2] Recent U.S. examples include the aborted attempt of China's CNOOC to acquire Unocal and the failed Dubai Ports purchase—both killed by political backlash in the U.S. Congress—the recent action against the Chinese paper industry by the U.S. Commerce Department, and the Schumer-Graham legislation now under discussion in Congress.

solar energy and *stored* solar energy—in the form of natural resources, human capital, physical capital, and technology—to create *work*, or economic activity. Resource flows within and between nations are driven by price and return gradients according to the second law of thermodynamics[3]. Policies impact resource flows by steepening or flattening price and return gradients, providing incentives, or signals, for entrepreneurs to change their behavior.

This framework allows us to draw on recent important developments in non-equilibrium thermodynamics (NET)[4] pioneered by Ilya Prigogine that can help us understand the dynamic behavior of systems, including economic systems, over time. NET sheds light on questions of so-called market failures, including recessions, asset market bubbles, and trade wars.

In the next section I will summarize this framework. Then in later sections I will extend the approach to protectionism, which we will view as a form of *turbulence*—an unavoidable by-product of the rapid adjustments that are driving today's strong global economic growth. As such, policy cannot eliminate protectionist forces; but it can mitigate their most harmful effects on growth and stability.

Thermodynamic Framework

In this section I discuss a framework for thinking about growth and protectionism based on the laws of natural science that I am developing at the Chinese Academy of Sciences . To Democritus, writing 2500 years ago, the universe was comprised of "atoms and the void.[5]" To a modern physicist, there is only matter and energy. In fact, as Einstein (1905) showed in his famous equation, $E=mc^2$, matter and energy are interchangeable. In

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[3] The Second Law states that matter and energy have a tendency to disperse to a less orderly form, or in Clausius's words, "heat cannot by itself pass from a colder to a warmer body" (Kondepudi (1998), p. 84). The Second Law was established by Sadi Carnot in 1824, Rudolph Clausius in 1850 and Lord Kelvin in 1851, and was applied to chemical reactions by Josiah Gibbs in the 1870's. Economists will recognize Josiah Gibbs's most famous student—Irving Fisher.

[4] For a review of recent writings in NET see Schneider and Sagan (2005) and Prigogine (1997).

[5] Dressler and Potter, (1991) p. 1.

this view all activity on earth can be viewed as energy transformations driven by the flow of energy from the sun[6].

Mining solar energy to produce usable products, the subject of physics and engineering, is the domain of thermodynamics, as Richard Feynman (1989) explains,

> There is a fact, or if you wish, a law, governing all natural phenomena that are known to date. There is no known exception to this law—it is exact as far as we know. The law is called the *conservation of energy*.
> …Although we know for a fact that energy is conserved, the energy available for human utility is not conserved so easily. The laws that govern how much energy is available are called the *laws of thermodynamics* and involve a concept called entropy for irreversible thermodynamic processes. (pp. 4-1 to 4-8)

In the next section we will describe the link between thermodynamics and economic activity.

Work, Coherent Energy, and Economic Activity

Orthodox macroeconomics, developed following last century's Great Depression, is obsessed with analyzing who is spending money—consumers, businesses, government, or foreigners. More recently, supply-side economics, pioneered by 1999 Nobel-winner Robert Mundell, has focused attention on the resources available for production and on the incentives to use resources productively. To a physicist, there is only one resource that drives all activity on earth—the energy from the sun.

The purpose of macroeconomics is to measure and explain variations in economic activity—how much work the people in an economy perform during a given time period. Work, creates wealth and generates incomes. Work earns paychecks; work generates profits. In the aggregate, we can refer to this as Gross National Work (GNW).

Physicists have been measuring work since Galileo rolled a ball down an incline 500 years ago. To a physicist, work is a result of energy transfer. Physicists refer to work as *coherent motion*, and refer to *incoherent motion* as heat, as illustrated in Figure 1.

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[6] Stated by Boltzmann (1886), p. 24, as quoted in Schneider and Sagan (2005).

Figure 1
Work vs. Heat

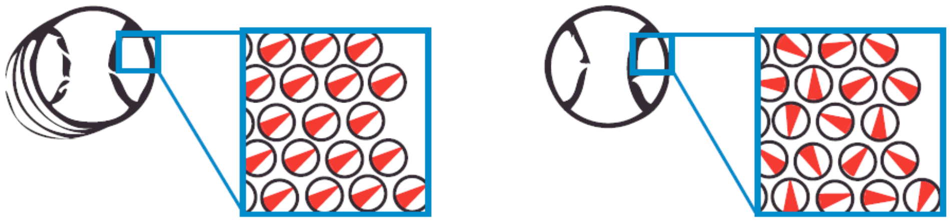


Figure 1(a): Coherent Energy (Work)

Figure 1(b): Incoherent Energy (Heat)

To illustrate, think of two baseballs. Every particle in the baseball on the left, in Figure 1(a), thrown by a major league pitcher, is moving at 97 miles per hour towards the catcher's mitt. This is an example of *work*, also known as *kinetic energy, coherent energy, or order*.

Every particle in the baseball on the right, in Figure 1(b), is also moving at 97 miles per hour; but the baseball, viewed as a macro object, or system of particles, is not visibly moving. In this case, we have set the particles in motion by heating the baseball to a high temperature; the particles are moving rapidly in random directions, colliding with each other. This is an example of *heat, thermal energy, incoherent energy, or chaos*.

In economics, the picture on the left represents economic activity, where people are engaging in work to produce goods and services. The picture on the right represents cost, wasted effort, inefficiency, or conflict. The policy that encourages people to produce the largest possible value of work, or coherent energy, and the smallest amount of heat, given available resources, will result in the highest national income and the highest living standard.

There is a law of conservation of energy stating that energy can be transformed but never created or destroyed; unfortunately, there is no law of conservation of work. Work can be destroyed by policies that blunt incentives or make it more difficult (require more energy) for people to create wealth. Subsidies, tariffs, quotas, price controls, excise taxes, and burdensome or unpredictable regulations reduce work. Taxing an activity destroys work. A government should collect tax revenues in the manner that destroys the least work. Taxing work directly, by imposing taxes on income and profits, directly destroys work.

In markets, work is created when people respond to price and return differences that signal profitable opportunities to redeploy resources. In flow markets we call it supply and demand; in asset markets we call it portfolio balance. Both are driven by the second law of thermodynamics. Arbitrage, fed by price and return differentials, is the only concept we need to build a macroeconomic theory of work.

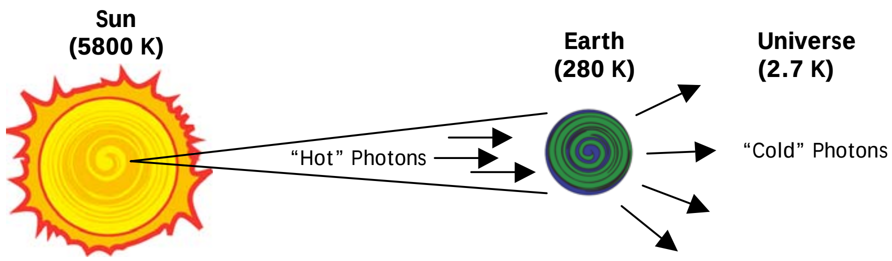
Trade—whether within a community or between nations—increases the aggregate amount of work and raises aggregate income, as economists have agreed since the time of David Ricardo. But changes in trade patterns also require changes in resource allocation that have important impacts on individuals. As we will see in a later section, these changes can lead to turbulence in the form of social instability and protectionism.

Solar Energy Drives All Work

The flow of energy from the sun drives all activity, including economic activity. The Second Law of thermodynamics states that heat flows from warm to cold bodies. The difference between the 5800 K surface temperature of the sun, and the temperature of the earth, at 280 K, causes energy to flow from the sun to the earth in the form of radiation, producing work and heat on earth[8].

[8] The sun is a giant thermonuclear reactor that has been turning 5 million tons of hydrogen into helium each second for 5 billion years. Its temperatures vary from 15 million K at its core, to as low as 4000 K in sunspots. The rate of energy delivered to earth by the sun, 1.36 kilowatts (KW) per square meter, has long been referred to as *the solar constant*, although recent measurements show it varies by as much as .2%, which equals four times all human energy consumed on earth today. In all, only two billionth of total solar energy falls on the earth. But even this tiny fraction amounts to 5 million horsepower per square mile.

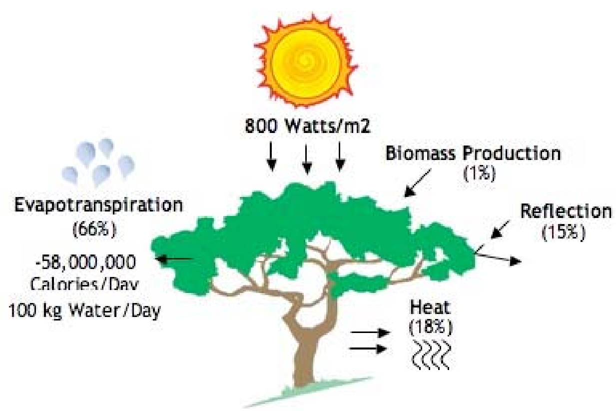
Figure 2
Sun-Earth Flux



(Schneider and Sagan 2005)

About two-thirds of the radiation that hits the earth's atmosphere hits the surface; the remaining third is absorbed by clouds as heat or reflected back into space. Only about 1% of captured energy is converted into stored energy in organic molecules through photosynthesis. The energy stored in this way each year is about 10^{18} kilojoules, which is about 30 times current global energy consumption. (Atkins, p. 210)

Figure 3
Storing Solar Energy



Source: Schneider and Sagan (2005)

Through this seemingly wasteful collection process, stored sunlight makes the earth inhabitable. Sunlight trapped by photosynthesis produces the carbohydrates that feed the plants themselves, which in turn provide the food for plant-eaters and animal-eaters, including humans.

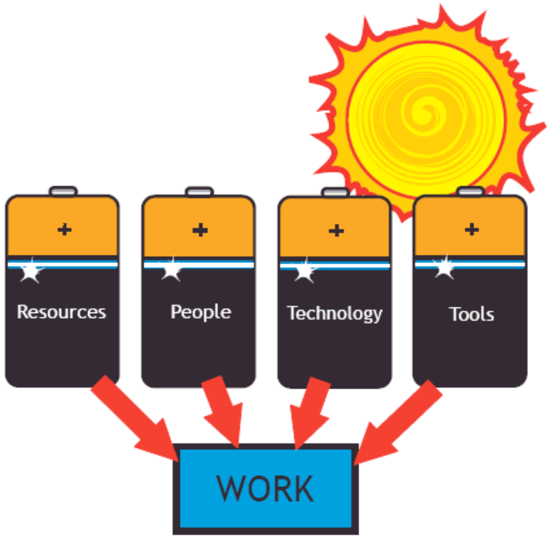
Economic activity is the directed transformation and distribution of solar energy to satisfy the needs of man. We can think of stored solar energy as having a *solar vintage*, similar to the vintage marked on a bottle of wine, marking the year the solar energy captured in its organic molecules reached the earth.

For most of history, people earned a bare subsistence living as hunter/gatherers by harvesting current and recently stored solar energy stored as living plants and animals. Hunter-gatherers harvested only very young solar vintages; for them the oldest vintage available was the wood they used for fuel.

Modern man enjoys a dramatically higher living standard than hunter-gatherers because we have learned to augment current solar energy by reaching deep into the wine cellar of vintage sunlight to mine energy stored in the distant past. Sunlight stored in the form of coal reached the earth 350 million years ago; coal surpassed wood as man’s principal source of fuel in the closing decades of the nineteenth century. Coal was succeeded, in turn, by oil, then gas, after 1950.

But fossil fuels are only one form of stored energy; their consumption accounts for only a small percentage of GDP in most nations. The bulk of energy used to produce work is the energy stored as human capital (stored food energy, knowledge, and experience), as technology (stored knowledge), and as tools (technology and knowledge stored as physical capital goods), depicted in Figure 5. All are mechanisms for storing solar energy for a later time when it can be used to produce work.

Figure 5
Stored Energy Powers Work



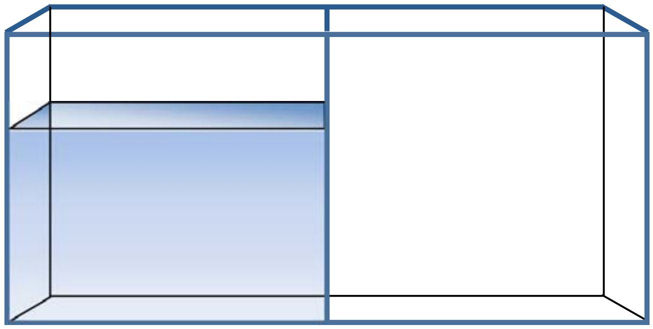
In this framework, wealth represents our command over stored energy. People use stored energy to produce work, which is valued in markets using prices that reflect relative scarcities. National income is a measure of gross national work, the price-weighted sum of all work.

Arbitrage Drives the Global Economy

Stores of energy are not evenly distributed around the globe. Oil and gas are concentrated in the Arabian Gulf, with significant deposits in Russia, Africa, South America, and Australia. Technology and physical capital are concentrated in North America, Western Europe, and Japan. Human capital is concentrated in Asia.

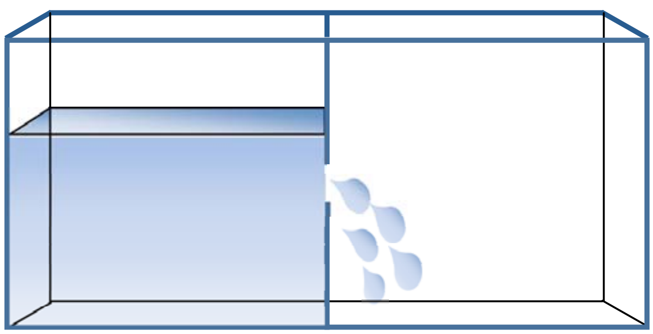
If national economies are closed, without trade, then national endowments of stored energy will determine relative prices, which will vary from nation to nation. International trade theory refers to this closed system as *autarky*, illustrated in Figure 6 by two compartments of a washtub, separated by a barrier.

Figure 6
Closed Systems – Autarky



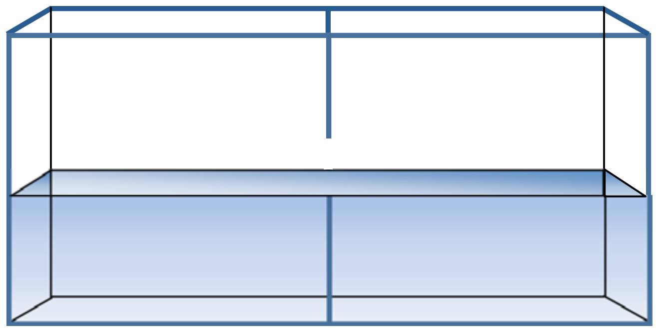
When two *closed systems* are brought into communication to form a single *open system*, as in Figure 7, the second law of thermodynamics forces energy to disperse. The pressure differential caused by different water levels forces water to flow from the full tank into the empty one. In economics, this represents arbitrage behavior; entrepreneurs redeploy resources in response to price or return differentials.

Figure 7
Open Systems - Arbitrage



In the absence of continuing energy flows, the end result will be *thermal equilibrium*, illustrated in Figure 8, at which no further *net* energy flow takes place. Similarly, in economics, a *market* is defined as an area in which prices tend to converge to a single level. This *law of one price* in economics corresponds to thermal equilibrium where no further net flow will take place.

Figure 8
Thermal Equilibrium—Law of One Price



In today's connected global economy, stored energy imbalances lead to price and return differentials that trigger arbitrage activities in which entrepreneurs redeploy resources toward areas of greater relative scarcity. This can be viewed in two equivalent ways.

From the point of view of an owner of physical capital, shown in Figure 9, capital is abundant the United States, and relatively scarce in China and India. Returns on capital will be lower in the U.S. than in China and India; the relative price of capital goods will be higher in China and India than the United States. Creating a single open market by opening trade will create incentives for owners of capital to redeploy capital out of the U.S. and into China and India. This will take place through Foreign Direct Investment (FDI) and Portfolio Investment. Capital redeployment tends to reduce the return differential, forcing returns to converge over time.[10]

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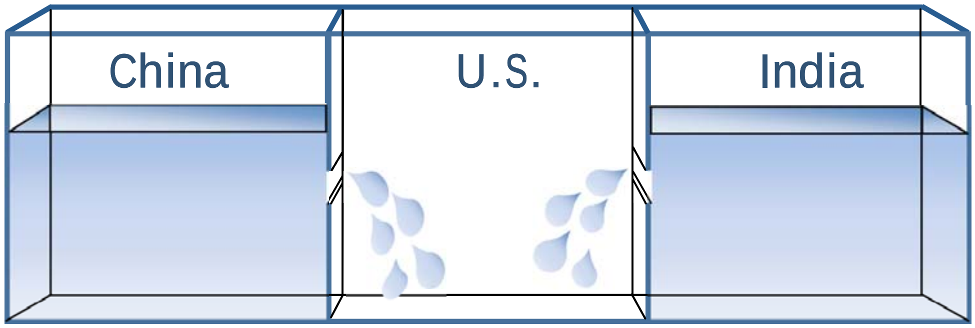
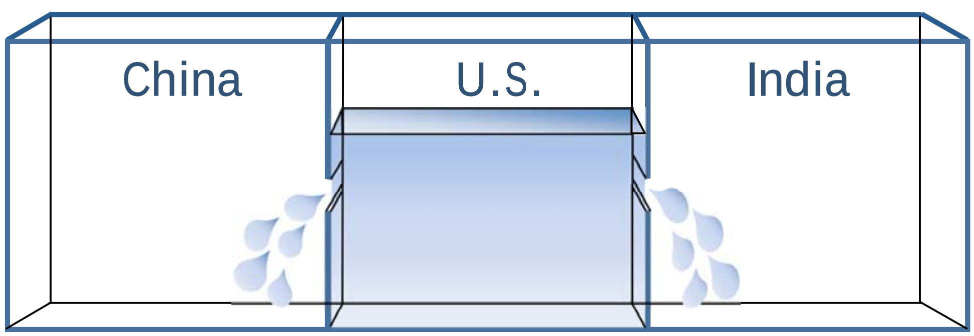
[10] American investors may not see this ; financial statements of U.S. public companies report the profits and returns of companies *listed* in America, not the returns on capital *deployed* in America. Capital redeployment is one of the major reasons why U.S. companies have been reporting record profits as a percentage of GDP in recent years.

Figure 9
Arbitrage—Physical Capital



From the point of view of an owner of human capital, the situation is depicted in Chart 10. Human capital is abundant in China and India relative to the U.S.; wages and incomes are lower in Asia than the United States. Linking the three nations will result in a net flow of human capital from Asia to the U.S., raising wages in China and India, while lowering wages in the United States. The influx of human capital into the U.S. will take the form of immigration (legal or illegal), outsourcing, and imports of goods and services, which embody stored human capital.

Figure 10
Arbitrage—Human Capital



Economists typically describe trade-driven resource adjustments as smooth and gradual. That may have made sense when resource redeployments principally took place as international trade in physical goods. After all, potential resource transfers can be very large relative to the capacity of the communication channel linking the systems. For example, it takes two weeks to load goods onto a ship in Shanghai, sail to Long Beach, and unload the cargo; and the number of containers a ship can carry is limited by its designed capacity, currently less that 14,000 standard 20-foot containers for the largest ships. Traditional trade adjustments occur gradually over many years.

Nonequilibrium Thermodynamics (NET)

Through most of its history, thermodynamics has also assumed that adjustments toward thermal equilibrium were smooth and gradual; such adjustments are known as *reversible* thermodynamic change. Reversible change assumes that the distance from equilibrium is very small—the gradient is almost flat—and that adjustment takes place at infinitesimally slow speed.

Path-breaking recent work by Nobel Prize winning chemist Ilya Prigogine (1997), however, showed that we are living in a world of irreversible nonequilibrium processes and that distance from equilibrium is a fundamental parameter of nature. As the distance from equilibrium, and the corresponding temperature, pressure, or energy gradient, increases beyond a certain point, known as the bifurcation point, qualitative changes in system behavior appear leading to abrupt, unpredictable, and discontinuous change, produce completely new coherent structures, which Prigogine referred to as *dissipative systems.*[11] When the distance from equilibrium increases still further beyond a second critical point, randomness forcefully reappears in a regime characterized by erratic behavior in time emerges; this is the chaotic, unpredictable behavior that engineers refer to as *turbulence*.

[11] Today, this dynamic new field of study is variously called chaos theory, complexity, complex adaptive systems, network theory, self-organizing systems, emergence, nonequilibrium thermodynamics, or simply NET. See the work of Barabasi (2002), Buchanan (2002), Gleick (1987), Holland (1995), Kauffman (1993), Nicolis and Prigogine (1989), Prigogine (1996), Schneider and Sagan (2005), Strogatz (2003), Watts (2003), Watts (2002a), and Watts (2003b). The father of them all, however, is Irwin Schrödinger's (1944) little book, *What is Life?,* based on three lectures delivered at Trinity College, Dublin in 1943. This book , arguably, spawned both molecular biology and NET, the science of creating order from disorder.

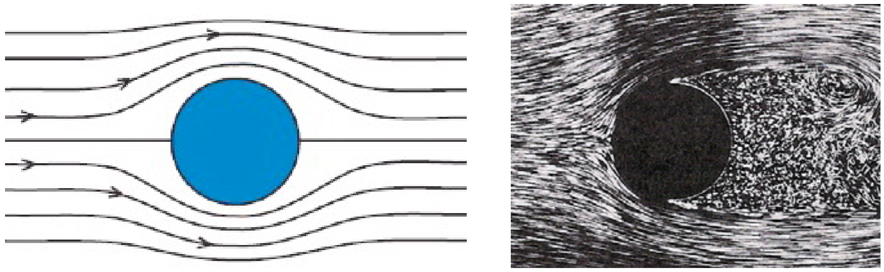
Figure 11
Mobile Capital

Today's networked global economy is certainly far from equilibrium, as measured by price, wage, or return differentials, making nonequilibrium thermodynamics extremely relevant for current policy analysis. Nations today are not only connected by slow-moving ships of limited capacity; they are connected by fiber-optic communications networks, depicted in Figure 11, which can transport vast amounts of resources at the speed of light. These links have dramatically increased the responsiveness of the global economy to price and return differentials. The resulting capital flows, outsourcing, cross-border M&A, supply-chain, and restructuring activities have also generated political backlash in many countries, the social manifestation of turbulence, raising important questions of economic and political stability.

Turbulence

Leonhard Euler, the Swiss mathematician and physicist, revolutionized the analysis of fluid dynamics in 1753 when he derived the set of partial differential equations that describe the motion of a fluid of zero viscosity (Johnson (1998)). Figure 12 (a) illustrates the flow of a non-viscous fluid around a cylinder (Acheson (1997), p. 123). Actual fluids behave very differently due to friction as shown in the photograph in Figure 12(b) of a real fluid with positive but small viscosity flowing past a cylinder. The area downstream (to the right of) the cylinder is characterized by chaotic turbulence. Viscous flows are not, in general, reversible.

Figure 12
Fluid Motion Past a Cylinder
(a) Hypothetical non-viscous fluid
(b) Actual fluid of positive viscosity

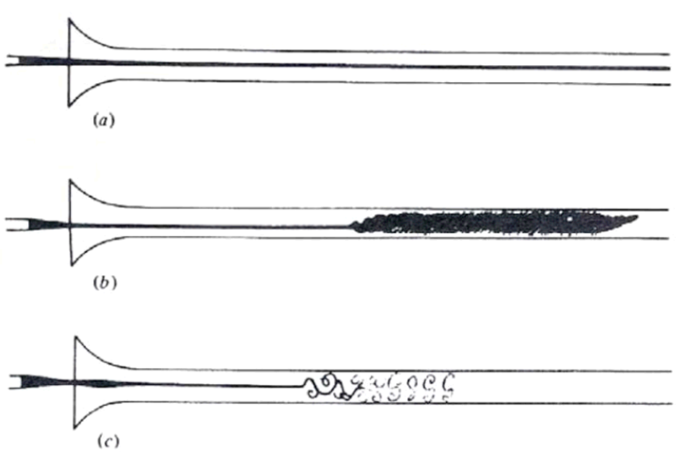


(a) (b)

Source: van Dyke (1982)

Increasing velocity leads to turbulence. Figure 13 shows drawings from experiments conducted by Osborne Reynolds in 1883. Reynolds marked the water drawn through a tube with a streak of visible dye to study the fluid motion. At very low velocity the flow was smooth, or *laminar*, as shown in Figure 13(a).

Figure 13
Reynolds Experiments in Fluid Motion

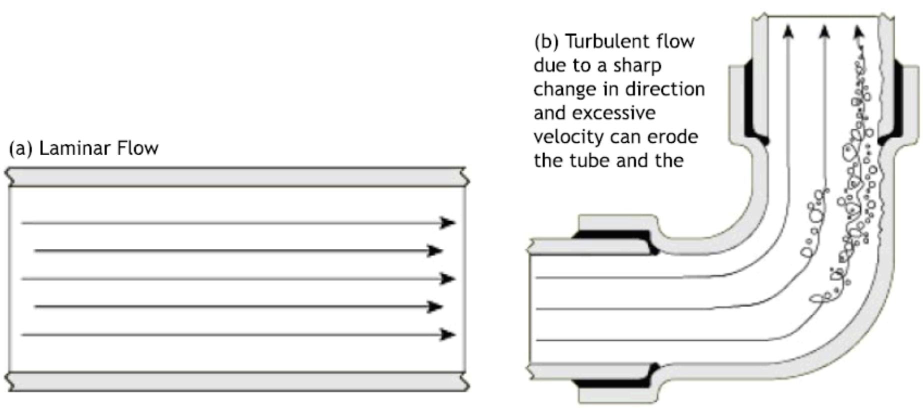


Source: Acheson (1997) p. 134.

As the velocity increased, however, there was always a point at which an arbitrarily small further increase in velocity would cause the flow to transition from laminar flow to turbulence, as shown in Figure 13(b), which was revealed to be a mass of more or less distinct curls when lit by an electric spark, as shown in Figure 13(c). According to Acheson (1997, p. 134), "this sudden transition from laminar flow to turbulence as the speed is gradually increased is still one of the deepest problems in classical physics".

This transition from laminar flow to turbulence is well known by engineers. Figure 14, taken from the website of the Canadian Copper & Brass Development Association, shows that excessive velocity, sharp changes of direction and flow obstacles can create turbulence, which erodes the tube and fitting, damaging the system. Less obviously, turbulence reduces flow pressure by narrowing the effective diameter of the tube used to transport fluid; pressure loss varies approximately with the square of flow velocity.

Figure 14
Laminar Flow (a) and Turbulence (b)



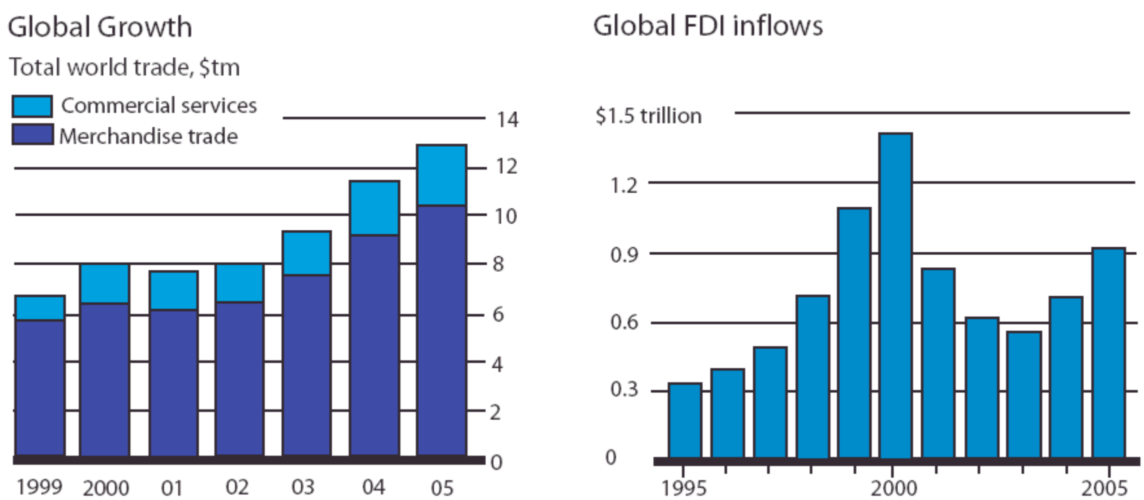
source: http://www.coppercanada.ca/publications/is-97-02-publication-e.html. (Downloaded July 9, 2007)

Just as increasing velocity and sharp changes in direction can produce turbulence in flow of physical fluids, increases in the velocity of trade and capital flows as well as sharp changes of direction in employment patterns and incomes can create turbulence in human societies in the form of political unrest and social instability. Social turbulence leads to pressures for protectionist policies that promise to return the society to its former stable condition. As we will see below, these promises are seldom realized.

Accelerating Growth; Rising Protectionism

The factors described earlier in the paper have increased international trade and capital flows, as shown in Figure 15. They have also increased growth. Global economic growth was an incredible 5.4% in 2006, compared with 2.9% during 1950-1973, when Europe and Japan were rebuilding their economies after the war, and 1.3% during the 1870-1913 industrial revolution. The IMF predicts 5% growth for both 2007 and 2008, which would mark the sixth straight year of growth in excess of 4%. (http://www.bloomberg.com/apps/news?pid=20601087&sid=aiAhpXO7ydZ4&refer=home.)

Figure 15
Rising Trade and Capital Flows



Source: WTO, UNCTAD

Strong growth and capital redeployment towards fast-growing emerging markets like China and India have sharply increased profits as a share of GDP, as shown in Figure 16, which has supported sustained increases in stock prices and net worth, especially in emerging market countries.

Figure 16
Rising Global Profit

As the previous section suggests, however, rapid growth and accelerating trade and investment flows produce turbulence in social systems as well, in the form of economic and social instability. This is the source of rising protectionist pressures around the world.

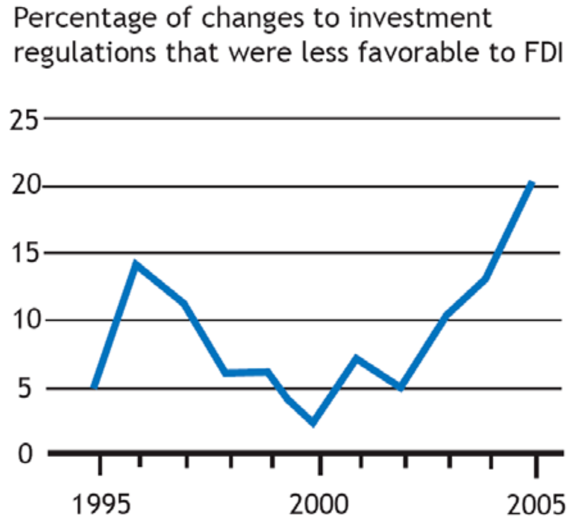
There is always a certain level of protectionist background noise in international trade and finance, as politically powerful industries use government influence to jockey for advantage against foreign rivals. In recent years, however, the noise level has become deafening as country after country has moved to adopt rules limiting free trade and investment flows. Selected examples include:

- In 2002, ahead of the mid-term elections, the U.S. imposed a 30% tariffs on Canadian lumber, and imported steel. Congress passed legislation making it illegal to sell catfish imported from Vietnam using the name "catfish, " provoking retaliation from the EU and Japan.
- In 2005, the U.S. Congress effectively blocked the announced acquisition of UNOCAL by CNOOC, the Chinese oil company, citing national security concerns. In early 2006, a second uproar in Congress blocked UAE company Dubai Ports World from acquiring the U.S. port management interests of British company P&O.
- Earlier this year Carlyle, the U.S. private investment firm, was forced to scale back its announced acquisition of China's Xugong Construction Machinery to a minority stake following intense political pressure. Chinese leaders cited national security worries.

- U.S. protectionist moves against China are accelerating fast. China announced the end of the fixed RMB/$ policy in July, 2006 to accommodate growing pressure from the U.S. over the U.S. trade deficit with China and to deflect pressure in the U.S. Congress to pass China-directed protectionist legislation endorsed by Senators Schumer and Graham. More recently, the U.S. blocked Chinese fish imports and U.S. media focused on quality problems in Chinese goods.
- China retaliated by blocking shipments of mineral water, orange pulp, and pistachios citing quality and health issues.
- Germany is drawing up plans to stop strategic assets—including telecom, banks, post, energy, and logistics—from being sold to foreign sovereign investment funds and 'finance houses' i.e., private equity and hedge funds.
- French President Sarkozy succeeded in striking the words "free and undistorted competition" from the EU's treaty objectives last month.
- Italy blocked the acquisition of Telecom Italia by Spain's Telefonica SA, forcing the buyer to team up with three local partners.
- Canada is considering restricting foreign acquisitions after last year's purchase of steelmaker Dofasco by France's Arcelor.
- Russia is preparing a list of 39 strategic sectors, including natural resources and technology, where foreign ownership will be limited.
- Italy forced Spanish firm Telefonica SA to team up with three Italian partners to purchase Telecom Italia.
- Venezuela is nationalizing its telecom sector; Bolivia is nationalizing its energy sector.

There are still free trade voices, of course, including EU Internal Market Commissioner McCreevy and new British Prime Minister Gordon Brown. Unfortunately, their voices are increasingly drowned out by protectionists. So far the damage is hard to see. Economic growth is still strong and FDI flows are robust. M&A transactions involving two geographies separated by differing language, law, culture, currency, and steering wheel placement are at all time highs. In the first half of 2007, the number of cross border transactions increased 17% compared with the same period in 2006. But investment regulations are beginning to move against global investors, as Figure 17 shows.

Figure 17
Protectionism—FDI



source: UNCTAD

I am convinced that today's chorus of protectionist actions represents more that the profit-seeking actions of a few special interest groups. Today, when a political leader announces a new protectionist measure, crowds cheer. I believe that rising protectionism, nationalism, and social instability are rooted in the turbulence caused by rapid economic change. Rapid economic change raises average incomes but it creates new industries and destroys others, changing the lives of many people. Those, whose fortunes have been temporarily or permanently reduced, as well as those who are simply afraid of change, will appeal to the political process for relief; political leaders who promise to stop or reverse change will gain power over leaders who counsel openness.

Left unchecked, this process can lead to global trade war as country after country erects non-market barriers to the smooth flow of trade. Ultimately, these mounting frictions measures can produce system failure, akin to the blackouts caused by failures of an electricity network. As Hayek (1948, p. 77) first pointed out, markets are exquisitely efficient information networks that transmit signals on relative wants and scarcities to the people who need to make decisions using symbols we call prices. When non-market intervention prevents prices from carrying information (for example, non-price rationing caused by price controls) the system breaks down.

Rampant protectionism could also breed social and political instability and, ultimately, bring nations into conflict. Political instability would put all the gains of the past quarter century at risk. Schneider & Sagan (2005) argue that complex nonequilibrium thermodynamic systems—societies, political systems, ecosystems, and economies—share a universal feature; they regress to earlier, more hierarchical, less complex and less open forms of organization under conditions of environmental stress (plagues, wars and depressions) when turbulence reduces energy flow. This system property is known as the *Savonarola Effect* (Bloom, 1997), after the 15th century Dominican priest whose fiery sermons against the corrupt Catholic Church incited Florence mobs to burn books and works of art; Savonarola was, in turn, burned by the church in 1498. We see it today as the Patriot Act, wiretapping, and immigration restrictions following the September 11, 2001 terrorist attacks in America.

The unintended consequences of protectionism would be harmful for people living in developed countries; they would be a tragedy for the world's three billion poor people.

We can choose a better course. As our framework shows, turbulence is a natural and unavoidable by-product of rapid global growth. Although we cannot eliminate protectionism, there are things we can do to retard its growth and mitigate its harmful effects. In the final section, we will look at policies to do so.

Conclusions and Policy Recommendations

The laws of thermodynamics are the one set of laws that all humans must obey with no exceptions. This leads to some general conclusions:

1. Like the Second Law of Thermodynamics, there is a law of thermoeconomics that drives all economic change. Price and return differentials—price gradients—cause resources to flow from places where they are relatively abundant to places where they are relatively scarce.
2. Likewise, we have a law of acceleration. High-speed communications networks and efficient global capital markets increase the velocity of resource flows. This has created today's unprecedented growth of global GDP, profits, and wealth.
3. And a law of turbulence. Turbulence is a natural by-product of rapid growth.

4. Faster change has created turbulence in both developed and emerging economies due to frictions in people's behavior. Turbulence has given rise to today's climate of growing protectionism. It cannot be wished away; it can be mitigated.
5. Reducing frictions does not eradicate turbulence, but it allows a system to grow smoothly at a higher rate before experiencing turbulence, making turbulence less costly.
6. Policies to reduce frictions include training, education and relocation assistance for people experiencing change due to rapid global growth.
7. An education system that gives people the tools to adapt to change by emphasizing problem solving over rote learning will reduce turbulence.
8. Labor market policies that make it easy for companies and workers to change the nature of the work they do will reduce turbulence.
9. Policies that increase people's overall sense of security, such as reducing corruption, predictable rule of law, and a healthy environment with clean air and water, will reduce friction and turbulence.
10. A stable monetary environment with a predictable price level and a moderate, predictable tax system will reduce turbulence.
11. Policy makers who want to reduce turbulence must anticipate feedbacks from other nations. To do so, they must thoroughly understand other nations' political and economic systems.

The framework in this paper is based on science. Ultimately, however, science is about people. The reason we care about protectionism is its impact on the lives of families trying to feed, educate, and care for their children to give them a better future. Protectionism attempts to stop change. But change is inevitable. It is a better use of resources to prepare people for change by giving them a stable society with a growing economy and by forward-looking education that gives people the skills and flexibility they will need for the jobs of tomorrow's global economy.

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