WORKING PAPERS ON
CAPITAL AS POWER

No. 2014/02

Rethinking Profit
How Distribution Drives Growth

Blair Fix

April 2014

http://www.capitalaspower.com/?p=1155

Rethinking Profit: How Redistribution Drives Growth

Blair Fix
York University
blairfix@gmail.com

April 4, 2014

Abstract

Using a combination of heterodox economics and biophysical analysis, this paper investigates the relationship between economic distribution and the growth of material throughput. Empirical results show that the growth of "useful work" correlates with redistribution towards profit. Furthermore, increases in energy consumption are correlated with increases in the largest corporations' share of total employment. These results are synthesized to form a new theory linking profit, social hierarchy, and growth.

1 How is Distribution Related to Growth?

"*The social responsibility of business is to increase its profits*"
- Milton Friedman [22]

Neoclassical economics treats growth and distribution as separate and unrelated concepts. Marxists, on the other hand, have developed numerous theories of *crisis* that relate distribution to growth.[1] In this paper, I attempt to develop a very different type of theory based on a novel combination of heterodox economics and modern theories of complex, non-equilibrium systems. I argue that profit, in particular, plays an essential role in driving growth – but *not* because it is an incentive for innovation and hard work. Rather, I argue that profit is a means for *concentrating power* and *legitimizing organizational hierarchy*.

The approach presented in this paper offers a radical departure from both neoclassical and Marxist theory. Instead, I offer a new theory based

on empirical connections between profit, hierarchy, and growth.

$$profit \Longleftrightarrow hierarchy \Longleftrightarrow growth$$

I argue that this approach has the advantage of being *consilient* [66] with modern scientific understanding of complex, non-equilibrium systems – a claim that dominant growth theories cannot make.

1.1 The Neoclassical Approach

Neoclassical macroeconomic growth theory is a logical extension of the neoclassical theory of the firm. The latter treats the firm as a "black box". All that is known are inputs (labour and capital) and outputs (goods and services). Neoclassical theory posits the existence of a "production function" – essentially a formula – that can explain how the quantities of inputs are related to the quantities of outputs. The importance of the production function to neoclassical theory cannot be overstated. It forms the basis for numerous further derivations, including marginal costs and supply curves.

The neoclassical growth model for the entire economy is a metaphorically extension of the neoclassical model of the firm. Now it is the economy that becomes a black box, described only by inputs and outputs, and it is posited that a unique function exists that can quantitatively explain this input-output mapping. The Solow-Swan model [57] nicely demonstrates this approach (Eq. 1). Here capital (K), labour (L) and "technical progress" (A) mix together to create material output (Y).[2]

$$Y = (AL)^{1-\alpha} K^{\alpha} \tag{1}$$

[1] Marxist theories of crisis come in two main varieties: theories of over-accumulation [2, 32] and theories based on the declining rate of profit [7, 41]. Rather than explain why economic growth occurs, crisis theories have focused on why it periodically *fails to occur*. To be fair, Marxists have devoted much time to analyzing production and the accumulation of capital, but this has never culminated in a quantitative theory comparable to neoclassical growth theory. Because of this, I mostly contrast my work with the neoclassical tradition.

[2] In many ways the "technical progress" term is a fudge-factor that adjusts for the empirical inaccuracy of the Solow-Swan model. Without this term, the Solow-Swan model cannot account for a large portion of historical growth [4]. The introduction of the "technical progress" term is akin to physicists discovering that Newton's laws cannot account for the motion of the planets, and, rather than declare the theory wrong, they instead introduce a "God" function that explains away the error.

There are numerous problems with production functions. The first is that the choice of variables is essentially *arbitrary*. This is because a production function differs fundamentally from a *physical* input-output formula. Take, for instance, a chemical formula for the combustion of hydrogen.

$$2H_2+O_2 \rightleftharpoons 2H_2O \tag{2}$$

We can represent this in functional form as:

$$H_2O = f(H_2, O_2) \tag{3}$$

This function relates *physical* inputs with *physical* outputs. Any such formula is bound by dimensional constraints – the dimensions of both sides must be equivalent. However, a neoclassical production function is *not* a recipe for making a particular product; instead it is a mapping of *abstractions* onto *abstractions*. Only the labour input (L) can be considered to have any physical dimension (it is measured in person-hours). Capital (K) is a pure abstraction – the monetary value of all the heterogenous "stuff" that aids in production.[3] Similarly, the output Y is *never* measured in physical units – it is always measured in dollar value.[4] Thus, the production function has no physical meaning – its dimensions are not well-defined.

Furthermore, since both sides contain theoretical abstractions, there is no objective criteria for determining which abstractions are relevant. Why not also include the value of land, or further subdivide capital into different types [65]? All approaches are similarly valid, meaning the hope of finding a *unique* function is forever dashed.

Most importantly, for the present discussion, neoclassical growth theory makes no mention of *distribution*. In the Solow-Swan model, the pecuniary returns to each factor of production do not enter into the equation. This is because neoclassical distribution theory is conceptually separate from (and was developed much earlier than) the Solow-Swan model. Its central tenant is that income is derived from the *marginal productivity* of a particular factor of production. Therefore, both capitalists and workers receive income

[4]The ability to objectively quantify "capital" was thoroughly critiqued by Cambridge economists, in what is now known as the Cambridge Capital Controversy. See Cohen & Harcourt [15] for an excellent summary.

[4]In the neoclassical tradition it is assumed that the dollar value of output (as well as the dollar value of capital) corresponds with some physical quantity. See Section 1.4 for an explanation of the flaws associated with using prices as a measurement of physical quantity.

in proportion to their marginal productivity.[5]

The problem with this theory is its circularity. Productivity is measured in terms of the *monetary value* of what is produced [50]. But incomes affect both the costs of production and the purchasing-power for finished products. Thus, neoclassical measures of productivity are *intrinsically* dependent on how income is distributed [52]. It is a recursive theory – distribution is caused by marginal productivity, but marginal productivity is dependent on distribution.

In this paper, I reject neoclassical theory in its entirety, including its theories of growth and distribution. In place of neoclassical growth theory, I propose a biophysical treatment of the economy that focuses on the growth of energy consumption. In place of neoclassical distribution theory, I instead focus on hierarchy and power.

1.2 The Types of Income

Any discussion of distribution must begin by advancing a theory of how incomes are derived. For neoclassical economists, income is determined by the marginal productivity of a factor of production. For Marxists, income is a result of class struggle. Both of these theories have a common conception of income as a physical share of what is produced. Of course, this is true – a worker's wages ultimately allow the purchase of goods and services. In this sense, money is just a helpful intermediary. However, people often treat the flow of money itself as more significant than the flow of goods and services. Thorstein Veblen noted this peculiarity nearly a century ago:

> Under the price system, men have come to the conviction that money-values are more real and substantial than any of the material facts in this transitory world. So much so that the final purpose of any businesslike undertaking is always a sale, by which the seller comes in for the price of his goods; and when a person has sold his goods, and so becomes in effect a creditor by that much, he is said to have realized his wealth, or to have realized his holdings. *In the business world the price of things is a more substantial fact than the things themselves.* [62] (emphasis added)

If we begin by focusing only on the flow of money we can state the following truism: things that have a price *cannot be free*. Yet this triviality contains an important kernel of truth. Things that are free are necessarily

[5] Technically, capitalists receive income in proportion to the marginal productivity of their *capital*.

open-access and unrestricted; therefore, for something to have a price, access to it must be restricted. This act of restriction (or *enclosure*) is institutionally enshrined as the right to *private property*, and it forms the basis of all prices [13, 48]. Thus, if we are to understand income, we must understand the institutional framework (property rights regime) under which it occurs.

Modern systems of national accounts allocate income into five main categories: **wages**, **proprietor**, **rent**, **interest**, and **profit**. Each type of income is accompanied by a particular institutional arrangement, explained below.

Wages

Wages accrue to workers who "own" their labour but who do *not* own what they produce [39]. Since ownership is defined as an act of enclosure, this implies that a wage earner must have the ability to restrict access to his/her labour. Workers who do not earn income have either lost this ability (i.e. slaves) or have decided not to enforce it (i.e. domestic labour).

The enclosure of human labour can be magnified through group coordination in the form of unions and combinations. By refusing to work, these groups of workers reinforce the enclosure of their labour, thereby strengthening their bargaining position.[6]

For the present argument, it makes no difference if income is paid per hour (wages) or per year (salaries). All that matters is that control over what is produced belongs to the employer, not the employee.

Proprietor

Sole-proprietors[7] own their labour *and* the things they produce. The classic example of the sole-proprietor was in the so-called "putting-out" system of early capitalism [51]. Rural inhabitants produced goods that they then attempted to sell. Thus, the clearest distinction between wage labour and sole-proprietorship can be made by contrasting the factory system and the putting-out system. In the former, workers clearly did not own what they produced, while in the latter they did.

However, the modern proliferation of contract labour has blurred this distinction. For instance, in order to cut costs (on employment insurance,

[6] For empirical evidence linking union membership to labour's share of national income, see [6].

[7] Technically, Proprietor income also includes partnerships. Proprietorship is effectively a category for all businesses activity that is *not* incorporated.

pension plans, etc.), companies are increasingly insisting that work be done on a contract basis. Here, the worker is accounted as a sole-proprietor, but is often more like an employee. This demonstrates the inherent subjectivity involved in classifying income.

Rent

Rent implies ownership of a specific "thing". Thus, rent accrues to owners of land, infrastructure, and natural resources. However, it can also be earned by owning less tangible "things" like intellectual property. In the national accounting system, rent can only flow to a *person*, not an institution. Thus, when corporations and/or sole-proprietorships earn income by renting out property, it is automatically called profit and/or proprietor income (respectively).[8]

Profit

Profit flows to the owners of a business enterprise. Notice that I have *not* used the typical definition of profit as something that flows to owners of *capital* (as both Marxists and neoclassical theorists would define it). The problem with the traditional concept of capital is that it represents a physical and financial duality. Capital is simultaneously the machines and infrastructure that are used for production, *and* a financial magnitude. Both neoclassical and Marxist theorists agree that profit is a return on *physical* capital. However, this physical view of capital is extremely problematic. Many of the most profitable corporations own almost *nothing* tangible (i.e. Microsoft). What, then, does a Microsoft shareholder actually own? *Social* capital? *Knowledge* capital? The proliferation of different categories of so-called capital speaks to the poverty of this line of thinking.

Nitzan and Bichler propose that we abandon this approach entirely, and instead consider a business enterprise as nothing more than a legal structure [48]. Ownership of a business is a means to enclose all activity undertaken by this business. Since this activity can, in principle, be anything, the outcome is to make the concept of private property much more flexible, and in turn, more abstract. The physical "things" owned by a business are in a constant state of flux. General Motors can sell off half of its factories

[8]The rent category is further complicated by the accepted practice of treating home ownership as a *business* activity. Thus, the Bureau of Economic Analysis calculates an *imputed* rent for all owner-occupied buildings. To whom this rent is actually paid remains unclear.

(or move them to Mexico), but it still remains "General Motors". This peculiarity forces us to the conclusion that owners of a business enterprise own nothing but the institution itself – that is, legal control of all activity it undertakes. Thus, profit flows to the owners of business *institutions*.

Interest

Interest flows to those who own debt, where debt is defined simply as a quantified obligation [29]. By lending interest-bearing money, a creditor essentially purchases the rights to a future income stream – interest. In this sense, interest implies the most abstract form of ownership – ownership of nothing but an income stream itself.

Again, this is very different from the neoclassical and Marxist conception of interest. In these canons, capital exists as a physical and pecuniary duality. Profit flows to owners of *physical* capital, while interest flows to owners of *financial* capital. In neoclassical theory, both types of capital are seen as productive; however, for Marxists only physical capital is productive – financial capital is *parasitic*.

Modern business practices have made the distinction between profit and interest difficult to discern. For instance, take the purchase of corporate equity versus the purchase of corporate bonds. In both cases, the buyer parts with money in the hopes of receiving a future income stream. For the buyer, the income derived from equity (profit) is indistinguishable from the income derived from debt (interest).

However, there are important differences. Firstly, the return on debt is fixed by the rate of interest (although the value of the bond itself can fluctuate significantly, like any other commodity). The return on profit is *not* fixed. Secondly, in the event of bankruptcy, owners of debt are given priority over owners of equity (stockholders often lose everything). Lastly, owning equity confers the right to influence the operation of a business enterprise, while debt is a passive affair.[9]

1.3 The Differential Growth of Income

Now that we have defined the various types of income and attributed them to specific types of ownership, we can move on to the task of connecting

[9] An important exception to this passivity occurs when a company is *unable* to pay its debts and enters a state of *receivership*, meaning creditors take over control of the company.

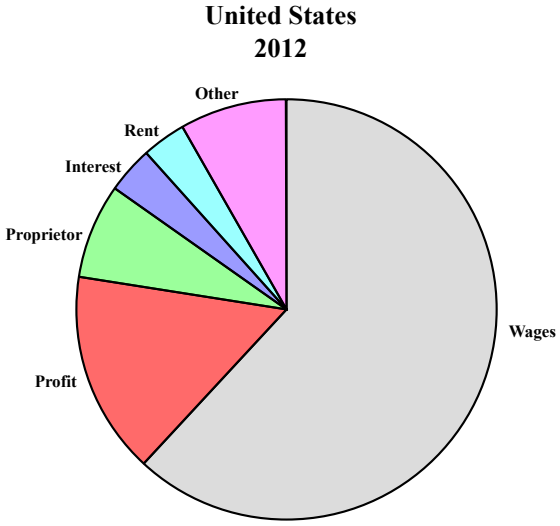

Figure 1: The Pecuniary Pie

Source: Bureau of Economic Analysis, Table 1.12.
National Income by Type of Income

them with growth. To begin, we should understand how standard theory makes this connection.

As mentioned above, both Marxists and neoclassicists regard money as a tool for purchasing the ultimate prize – material goods and services. The connection between income growth and material growth is thus straightforward. Since income is a claim on goods and services, *growth* in this income implies a growth in material purchasing-power, and thus, a growth in material affluence.

All is well and good until the scourge of inflation (or deflation) rears its ugly head. Inflation changes the purchasing-power of money, meaning an increase in income might not actually mean an increase in material consumption. This unpleasantry is typically resolved by resorting to price indices that can be used to "adjust" for inflation, thus returning us to the straightforward correlation between increases in "real" income and increases in material consumption.

Under a growth regime, we simply expect all types of "real" income to increase. Profit goes up, wages go up, rent goes up, and so on. But this focus on *absolute* changes in income distracts us from the more interesting problem of relative (or *differential*) changes in income. The question now

becomes: under a growth regime, who are the winners and who are the losers?

In order to investigate this question, we must discard the use of "real" metrics of income in favor of *differential* ones. We begin by conceptualizing different types of income as slices of a giant pecuniary pie (Fig. 1). We then compare relative changes in the size of each slice with relative changes in the material throughput of the economy. The empirical results of such an endeavor (discussed below) are quite surprising.

However, before we can continue, we must first find an *objective* way of measuring material throughput. This matter is not trivial. As I discuss below, economists' preferred metric of material output – "real" GDP – is deeply flawed.

1.4 Measuring Growth

Any act of measurement begins with an act of reduction. The observer must find a suitable unit for reducing the *qualities* of the universe to a single *quantity*. The choice of unit crucially affects this mapping of quantity onto quality. Thus, the concept of growth is only meaningful if we can first agree *on what it is that is growing*!

To state formally, measuring material production (Y) can only be done if we reduce it to a *single* quantity Q:

$$Y = Q \tag{4}$$

In principle, Q can be defined in terms of any unit. However, before selecting any particular unit, we must present arguments about why this unit is *meaningful*. Furthermore, for a unit to be effective, it must be socially agreed upon and it must not change over time and space.[10] Strangely, economists have chosen a unit (price) that does not uphold this simple principle.

In this section, I discuss the problems with using prices as a unit of material output. I then argue that energy (in the form of *useful work*) is the most meaningful way of measuring biophysical output.

[10] Readers might protest that Einstein's theory of relativity makes such a unit impossible, as time and space are inherently relative. However, relativity is based on the assumption that the laws of physics must remain the *same* in all reference frames. Thus, while time and space are distorted by gravity and velocity, the units of measurement are *not* distorted. A meter remains a meter and a second remains a second in any reference frame.

For instance, the *second* is now defined in terms of a specific number of oscillations of a cesium atom. This measure remains the same in any reference frame – the observer will always count the same number of oscillations in a second, no matter his speed or proximity

The Changing Meter Stick

Let us begin by looking not at the real world of heterogeneous production, but at an imagined world in which production is homogenous. In this world, only apples are produced, and they are all uniform. In this world, it makes sense to use "apples" as our unit of measurement. If, in the year in question, 300 apples were produced, then:

$$Y = 300\ apples \tag{5}$$

Now imagine that our imaginary economy begins to produce both 300 apples *and* 100 oranges (again, all uniform). Now production becomes:

$$Y = 300\ apples + 100\ oranges \tag{6}$$

The problem, however, is that we wish to express Y in terms of a single quantity – but as the old adage goes, you can't add apples and oranges. We must find a third unit that allows the comparison of "apples" and "oranges". Again, the unit must make sense. For instance, if we were shipping apples and oranges in a truck, a common unit of mass (kg) would make sense. Alternatively, if we simply wanted to eat them, a unit of energy (calories) would be more appropriate.

Since the study of prices is their domain, economists naturally choose *monetary value* as a common unit of aggregation. This seems reasonable: the price of an orange is much more important to the average person than almost any other metric (mass, energy, etc.).

Keeping with this tradition, we now measure output Y in units of dollars. In order to do so, we must know both the quantity of apples and oranges (Q_A and Q_O, respectively) and their unit prices (P_A and P_O). Production now becomes:

$$Y = Q_A P_A + Q_O P_O \tag{7}$$

Using the quantities from above (300 apples and 100 oranges) and adding prices of \$3 and \$1 for apples and oranges respectively, we get the quantity of production:

$$\begin{aligned} Y &= (300\ apples)(3\ \$/apple) + (100\ oranges)(1\ \$/orange) \\ &= \$900 + \$100 \\ &= \$1000 \end{aligned} \tag{8}$$

---

to mass. If measurements between two different reference frames conflict, it is because time and space are relative, not the units used to measure them. Thus, relativity of time and space does not mean relativity of units. Modern science fundamentally depends on the *universality* of its units.

Despite the definiteness of our answer, the matter is soon complicated when we realize that our chosen unit (the price of a commodity) *changes all the time*! For instance, the following year, we might produce the same quantity of apples and oranges, but the price of apples falls drastically to the same price as oranges (\$1). Then, without any physical changes, our measure of output is drastically reduced:

$$\begin{aligned} Y &= (300\ apples)(1\ \$/apple) + (100\ oranges)(1\ \$/orange) \\ &= \$300 + \$100 \\ &= \$400 \end{aligned} \tag{9}$$

Which one of these measures of material production is "correct"? Here lies the fundamental problem: *both of them are*! By choosing price as an appropriate unit for measurement, we immediately removed the possibility of attaining a single measure for the quantity of output because our unit is *not socially agreed upon over time*. No amount of intellectual gymnastics can get us out of this dilemma. Without an objective way to decide the year in which prices were "correct"[11], we must conclude that our measure is, in fact, *useless*.

For those who remain unconvinced by this conceptual argument using imagined numbers, we can apply the same reasoning to an empirical example (Fig. 2). Here we use historical quantity and price data for the production of cars and computers (mostly from the United States). Unlike above, now both prices and the physical configuration of production change. Again, we must choose a "base" year in which prices were "correct", and then *fix* this price across time. This creates a "real" GDP time-series for our 2 product economy. Different choices of base year drastically change the way we conceive of output growth.[12] Indeed, the economy simultaneously grows considerably and hardly at all!

[11]There is no such objective way to decide the "correctness" of prices [14]. Appeals to the contrary always imply an *additional* unit used to *explain* prices. For Marxists, this is a commodity's socially-necessary, abstract labour content. For neoclassicists, it reduces to the marginal utility derived from a commodity. In both cases, the argument for a "correct" price rests upon its correlation with a hidden quantity which (conveniently) cannot ever be measured. A more logically sound way to think about prices is that they are always "correct", *by definition*.

[12]Statisticians have recently become aware of this problem [58]. Their response has been to concede that the choice of base year is completely subjective. However, rather than conclude that this invalidates their measure (as I have), they have adopted a new method, called "chain-weighting", that uses a moving average for all base years. While this might seem reasonable, it is similar to measuring your height both in meters and feet

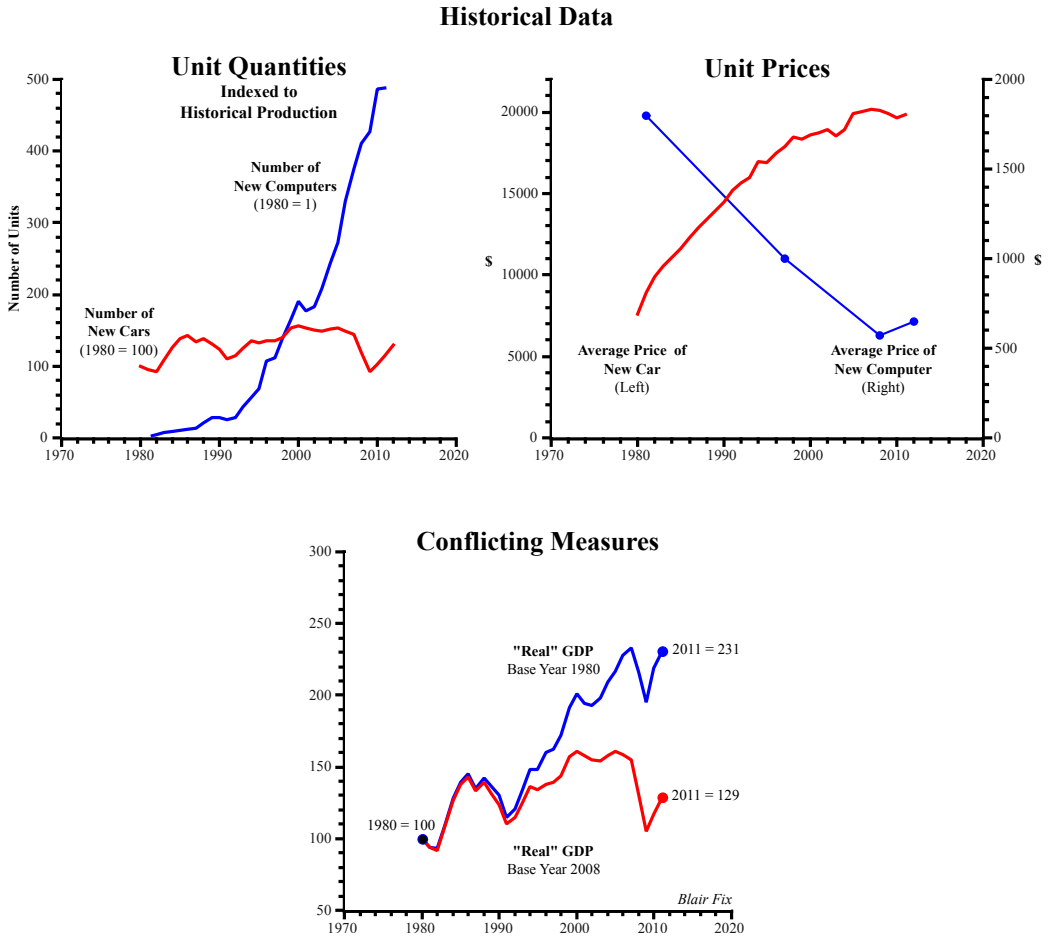

Figure 2: Measuring Production with a Changing Meter Stick

Sources: Quantity of cars from Wards Automotive Group, U.S. Car and Truck Sales, 1931-2012, at `wardsauto.com/public-data`. Quantity of computers from Jeremy Reimer, Total Share: Personal Computer Market Share 1975-2010, `jeremyreimer.com`. Price of cars from Bureau of Economic Analsys, Table 10.11, Average Price of a New Car, 1970-2011 (using domestic prices). Computer prices from Wikipedia entry for personal computer. . Note: computer price indices from US Bureau of Labor statistics are unsuitable here because they adjust for changing computer *quality* (ie: processor speed, memory, etc.).

A further difficulty with real GDP methodology is that commodities change qualitatively over time. Neither the computers nor the cars of 1980 looked anything like those of 2010. In order to combat this problem, statistical agencies attempt to measure these qualitative changes. However, we again encounter a number of fundamental problems. Firstly, we must subdivide a given commodity into relevant attributes. But how do we *objectively* decide those attributes that are relevant and those that are irrelevant?

Furthermore, once we have reduced a commodity to its constituent attributes, how do we decide their relative importance? The most popular method is called *hedonic quality adjustment*. The Bureau of Labor Statistics summarizes the process as follows:

> In price index methodology, hedonic quality adjustment has come to mean the practice of decomposing an item into its constituent characteristics, obtaining estimates of *the value of the utility* derived from each characteristic, and using those value estimates to adjust prices when the quality of a good changes. [9](emphasis added)

All quantitative comparisons require a unit of measurement. Here we see that the Bureau of Labor Statistics is attempting to measure the attributes of a commodity in *units of utility*. This is problematic because utility (a hypothetical psychic flux) cannot be directly measured; rather, it must always be "revealed" through prices. Like neoclassical distribution theory, hedonic measurement becomes circular. Distinguishing changes in price from changes in quality requires knowledge of consumer preferences; however, consumer preferences can only be measured through prices.[13]

To summarize, when measuring the quantity of production in terms of prices, we fall victim to a changing meter stick. When measuring changes in the quality of a commodity, our unit cannot actually be measured independently of prices.

The logical choice at this point, is to abandon prices as a unit for quantifying material output. A more appropriate approach – one that meshes nicely with the current state of scientific knowledge – is to use energy as our unit.

---

and then *averaging* both to arrive at your "true" height. The result is both meaningless and absurd!

[13]For an in-depth critique of hedonic quality adjustment and revealed preference theory, see [47] & [68], respectively.

The Consilience of Energy & Growth

Using energy as a metric for material growth is logical for two reasons. Firstly, the units are well defined. Secondly, and most importantly, it is physically meaningful. I will briefly elaborate on each of these points.

Astrophysicist Eric Chaisson writes that "[e]nergy – the ability to do work, or to cause change – is the most universal currency[14] known in natural science" [10]. What seemed like separate phenomena 200 years ago – heat, motion, light, electricity, magnetism, chemical potential – are now recognized to be different forms of a universal property we call energy. The science of energetics has made great advances in understanding and quantifying energy in its many forms. Because of its universality, energy is especially useful for the study of seemingly disparate processes.

There is virtually unanimous agreement that energy flows form the basis for all biological life [36, 38, 45, 49, 54]. Life is a subset of what are referred to by physicists as "non-equilibrium structures". Equilibrium, in thermodynamics, is the state towards which all isolated systems evolve. This state of maximum entropy can be thought of as the most boring situation imaginable – homogeneous temperature and pressure, no changes over time, and no organized structure.

Without flows of energy, all roads lead to equilibrium. However, the flow of energy through a system leads to the permanent departure from equilibrium and can cause the emergence of complex "dissipative structures" [36]. Along with single organisms, the notion of dissipative structure can be extended to include ecosystems and human societies. Indeed, the importance of energy to human societies is well-recognized [16, 17, 25, 31, 55].

Chaisson has offered compelling arguments that energy flow can be used as an indication of complexity.[15] That is, increases in complexity are predicated on increases in energy consumption. Thus, for human society to grow its structure, it must consume more energy. It only makes sense, then, to use energy as a metric for growth.

Having decided on our growth metric, a further complication arises: we must decide "where" to measure energy flow. I use the word "where" not in the spacial sense, but in the conceptual sense. The use of energy involves numerous transformations into numerous forms. Pre-analytic decisions about

[14] His use of the word "currency" is ironic, given the present discussion.

[15] In more technical terms, Chaisson argues for a correlation between complexity and *energy rate density* (energy flow per unit of time per unit of mass within the system). When applying this metric to human societies, we can simplify it to energy use per capita per year (ignoring the mass component, since the change in humanity's biomass will be essentially the same as the change in population).

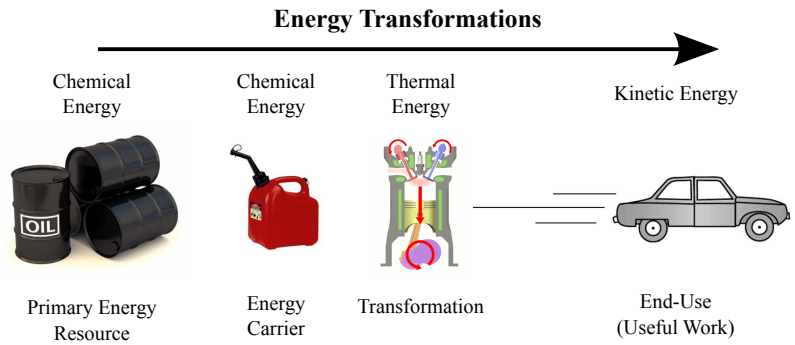

Figure 3: "Where" to Measure Energy Consumption?

accounting methodology will drastically change our final results.

In our example (Fig. 3), fossil fuel energy initially enters the economy in the form of crude oil. The crude oil is then transformed into gasoline, which involves some energy losses. The gasoline is burned in an internal combustion engine (turning chemical energy into thermal energy) before ultimately being transformed into the kinetic energy of an automobile. At each stage of this process, energy is lost. Thus, depending on "where" we measure its flow, we'll get very different data for the consumption of energy.

The most straightforward "place" to measure energy consumption is as it enters the economy as a primary energy resource (most statistical agencies use this method). Since there are relatively few varieties of primary energy, this type of accounting is relatively easy.[16] As we move towards end-use energy, accounting becomes increasingly complex, as the number of potential categories grows astronomically.

While some scholars argue that quantifying end-use energy is impossible [27], Robert Ayres and Benjamin Warr have made a laudable first attempt, calling their result "useful work" [3]. While I will not discuss the details of their methodology here, the process involves a conceptual simplification of the types of end-use categories and a calculation of the aggregate efficiency of each category (in a given year).[17]

The purpose of Ayres & Warr's useful work calculation is to enter it into

[16] Depending on how they are categorized, the basic primary energy forms are: fossil fuel, nuclear, hydro-electric, wind, solar, and biomass.

[17] Ayres & Warr create 5 categories of useful work: Electricity, Heat (low, mid, high), Mechanical Drive, Light, Muscle Work.

a production function capable of hind-casting the growth of "real" GDP [4]. Indeed, numerous scholars have made the link between growth in energy consumption and the growth in GDP [11, 12, 24, 33, 59]. All studies show a high correlation between the two. Few scholars, however, have made the conceptual leap that I make here: that energy is a valid growth metric unto itself.

Thus, I assert that useful work stands on its own as one of the best metrics of biophysical growth. To state formally, we are going to quantify material output (Y) in terms of useful work (U):

$$Y = U \tag{10}$$

Using this metric, and Ayres & Warr's data, we can now investigate the ways in which pecuniary distribution is related to biophysical growth.

1.5 Empirical Results

I begin by stating explicitly the methodology used for comparing growth with distribution. Equation 11 shows a sample calculation for wages. On the left side, we divide useful work (U) by population (P) to get useful work per capita. We then calculate the annual growth rate – signified by the hat symbol ($\widehat{\ }$). On the right side we divide the national wage bill (W) by the national income (NI), and then calculate its rate of change.

$$\left[\widehat{\frac{U}{P}}\right] \Longleftrightarrow \left[\widehat{\frac{W}{NI}}\right] \tag{11}$$

The results for this methodology, carried out over the 5 classes of income, are displayed in Table 1 in descending order of correlation. Positive correlation tells us that growth (positive change in useful work) is associated with an *increase* in the income share of the group in question. Conversely, negative correlation ($-$) means that growth is associated with a *decrease* in this group's income share.

The results are striking. Growth overwhelmingly occurs under conditions in which income is *redistributed towards profit* (see Fig. 4 for data visualization). Stated in the language of systems theory, growth and profit redistribution exhibit a *positive feedback* relationship, while all other income types exhibit *negative feedback* with growth. This finding is significant because only positive feedback relationships are capable of generating exponential growth [42]. Negative feedback is inherently stabilizing, causing systems to evolve towards a steady-state.

Table 1: Correlation Between Income Redistribution & Growth

Income Type	R^2
Profit	0.52
Interest	(−) 0.28
Rent	(−) 0.16
Wages	(−) 0.15
Proprietor	0.08

Note: Data is for correlation between annual growth rate of useful work per capita and annual change in each factor's share of national income. Profit correlation excludes the years 1932-33; when included R^2 drops to 0.23. All income data from Bureau of Economic Analysis, Table 1.12.. Data series: Corporate profits with IVA and CCAdj, Net interest and miscellaneous payments, Rental income of persons with CCAdj, Compensation of employees, Proprietors' income with IVA and CCAdj. Data for useful work and US population is from Benjamin Warr's REXS database.

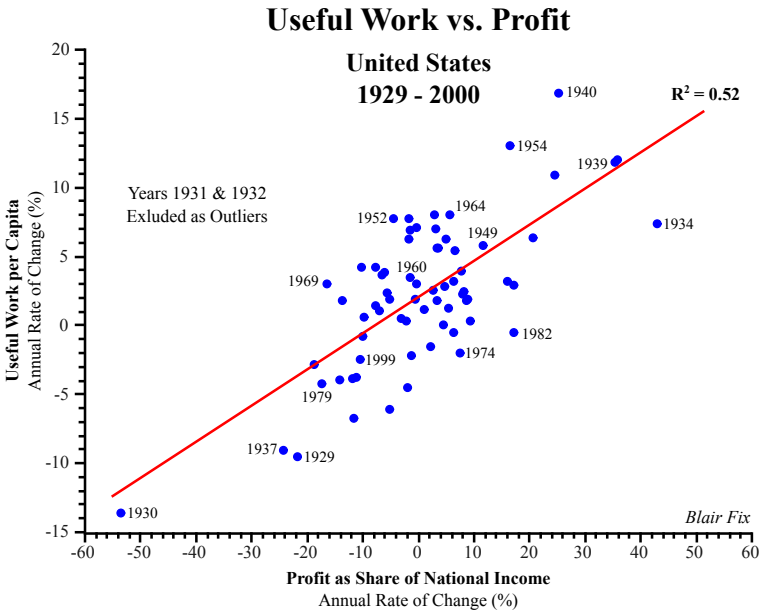

Figure 4: Redistribution Towards Profit

Sources: Data for useful work is from Benjamin Warr's REXS database. Profit and national income data are from BEA Table 1.12., National Income by Type of Income.

According to the evidence presented here, profit is the only income type capable of "driving" growth. But why should this be so? What is so special about profit? As I argue in the following section, there is nothing inherently special about profit *in principle*. Profit is nothing but an accounting practice. However, when it is coupled with a specific institutional arrangement, I argue that it becomes a *mechanism for concentrating power*.

Before proceeding, it is worth discussing what these results do *not* mean: namely, that increases in profit are an incentive for growth. Although this certainly seems to follow from Figure 4, it is a faulty conclusion. In order to understand why, we must clearly understand the difference between *differential* changes in income versus *absolute* changes.

Increases in *absolute* income are *immediately* evident to all participants. When a wage labourer gets a raise, he instantly feels richer. When profits increase, companies immediately celebrate. The immediacy of this situation means that absolute income can be treated as an incentive – i.e.: in response to rising profits, companies increase their investments.

In contrast, a change in differential income share is only evident *after* statisticians have calculated it (typically a year later). While individual participants instantaneously know the absolute size of their income stream, only later do they know what fraction of the total income "pie" this represents. This temporal lag makes differential income incapable of functioning as a behavioral stimulus.[18] In scientific jargon, differential income share is an *emergent* phenomenon that is only evident after the fact. This means it cannot possibly play a role in conscious decision-making.

If we compare changes in absolute income with rates of growth, we get much different results (see Table 2). Now profit, wages, and proprietor income are *all* correlated with growth in material output. Profit seems to lose its preferential status. What Table 2 tells us is that biophysical growth seems to correlate with growth of the *entire* pecuniary pie. But this is exactly what mainstream theory expects.

To restate, in neoclassical theory, profit is often assumed to function as an incentive that stimulates economic activity. The empirical results shown here neither disprove nor support this assertion. Only absolute income can

[18] In a sense, income is always differential, as are pecuniary incentives. People only want to earn more if they "know" that their income is smaller than that of others. This is the so-called hedonic treadmill, otherwise known as "keeping up with the Jones". However, this incentive is based on localized observation of inequality (ie: workers in the same neighborhood, capitalists in the same industry). The point is that no worker ever feels cheated because the national wage-bill has declined as a portion of national income. The scope of such a change is far beyond the perception of an individual.

Table 2: Correlation Between Absolute Income & Growth

Income Type	R^2
Profit	0.57
Wages	0.49
Proprietor	0.37
Rent	0.02
Interest	0.00

Note: Data is for correlation between *growth rates* of useful work per capita and nominal factor income. Correlation for profit excludes the years 1932-33. When included, R^2 decreases to 0.55.

function as a behavioral stimulus. However, since absolute growth in most types of income correlates with growth in useful work, we cannot conclude that profit is any more important than other types of income. Our results are quite ambivalent towards the neoclassical view of profit as an incentive mechanism for growth. At best, we can say that profit, wages, and proprietor income *all* play an incentive role.

The canon of political economy actually has very little to say on the topic of differential analysis. As such, the correlation between growth and profit redistribution is mysterious. In the next section, I attempt to shed light on the situation by investigating how the institutional context – hierarchy in particular – plays a role in how profit affects society.

2 The Institutional Context

My aim, in this section, is to investigate how profit can become a means for concentrating income in the hands of fewer people. My goal is to show that only when it is coupled with hierarchy, can profit concentrate income.

Before we proceed, let me first discuss how to interpret Figures 5–8. In each figure is a specific business institution. On the left-hand side, the black arrows show an income stream that is derived from some sort of vendible good or service. This income is then split into different accounting categories that vary according to the type of business.

All businesses incur costs, which flow to other individuals or institutions (where they count as income). The rest of the income stream is divided between profit, salary/wages, or proprietor's income. Wages and proprietor's income flow directly to individuals, while profit flows to institutions (dotted

lines). Whoever owns the institution commands the profit. The dotted red line represents decision-making power over how the original income stream is split. In each example, the arrows are labeled by accompanying percentages, signifying the size of the flow in relation to the original income stream.[19]

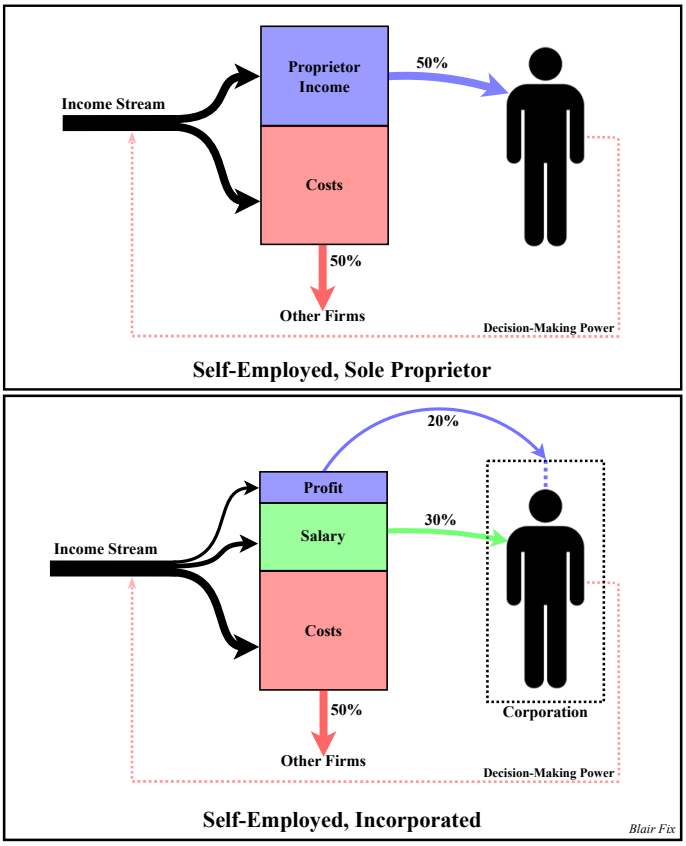

Figure 5: Atomistic Institutions

2.1 Atomistic Institutions

We begin with the simplest possible institutions, consisting of a single, self-employed person (Fig. 5). There are two possible configurations for such

[19]The allocations displayed in these diagrams are all hypothetical, but not unrealistic.

"atomistic institutions" – the sole-proprietorship and the self-employed individual who incorporates his/her business.

Modern accounting principles dictate that a sole-proprietor's income be called "proprietor income", and not profit. However, the distinction is in name only – both profit and proprietor income are defined as the total income (or "sales") less the costs of doing business. If a self-employed individual incorporates, this allows for a conceptual (and legal) separation of income into "profit" and "salary".

There are two main benefits to incorporating. Firstly, corporations are *limited liability* institutions, which allows a legal separation of business and personal assets. In the event of a bankruptcy, only business assets can be seized – personal assets remain safe. The second benefit is that profit is generally taxed at a different rate than a salary. For instance the effective US corporate tax rate was 21% in 2011. In the same year, the income tax rate for the highest income bracket was 35%.[20] Despite these differences, the two forms of business displayed in Figure 5 are, for all intents and purposes, the same.

Let us envision a society populated only by these two institutional configurations (similar to the one imagined by Adam Smith [56]). We ask the following question: what is the effect of redistributing income from wages and proprietor income towards profit?

There are two possible ways for this to occur. The first is if a sole-proprietor decides to incorporate his/her business. This would eliminate his/her proprietor income from the national accounts, but add wage and profit income in the same amount. The effect would be a change on paper, but no meaningful change in who actually controls this income (the same person in both cases).

Alternately, a self-employed person with an incorporated business might decide to allocate more income to profit rather than to salary (if tax rates changed, for instance). Again this has no meaningful effect outside of a re-categorization on paper: in both cases the individual's total income remains unchanged.

For a society populated entirely by atomistic institutions, it is difficult to see how an income redistribution towards profit would change anything but the abstract accounting category used to classify the income. Profit certainly could not function to concentrate income.

[20] Corporate tax rate is calculated by dividing total before tax profit by total tax collected, using BEA Table 1.12. Income tax rate is from IRS Table 23, U.S. Individual Income Tax: Personal Exemptions.

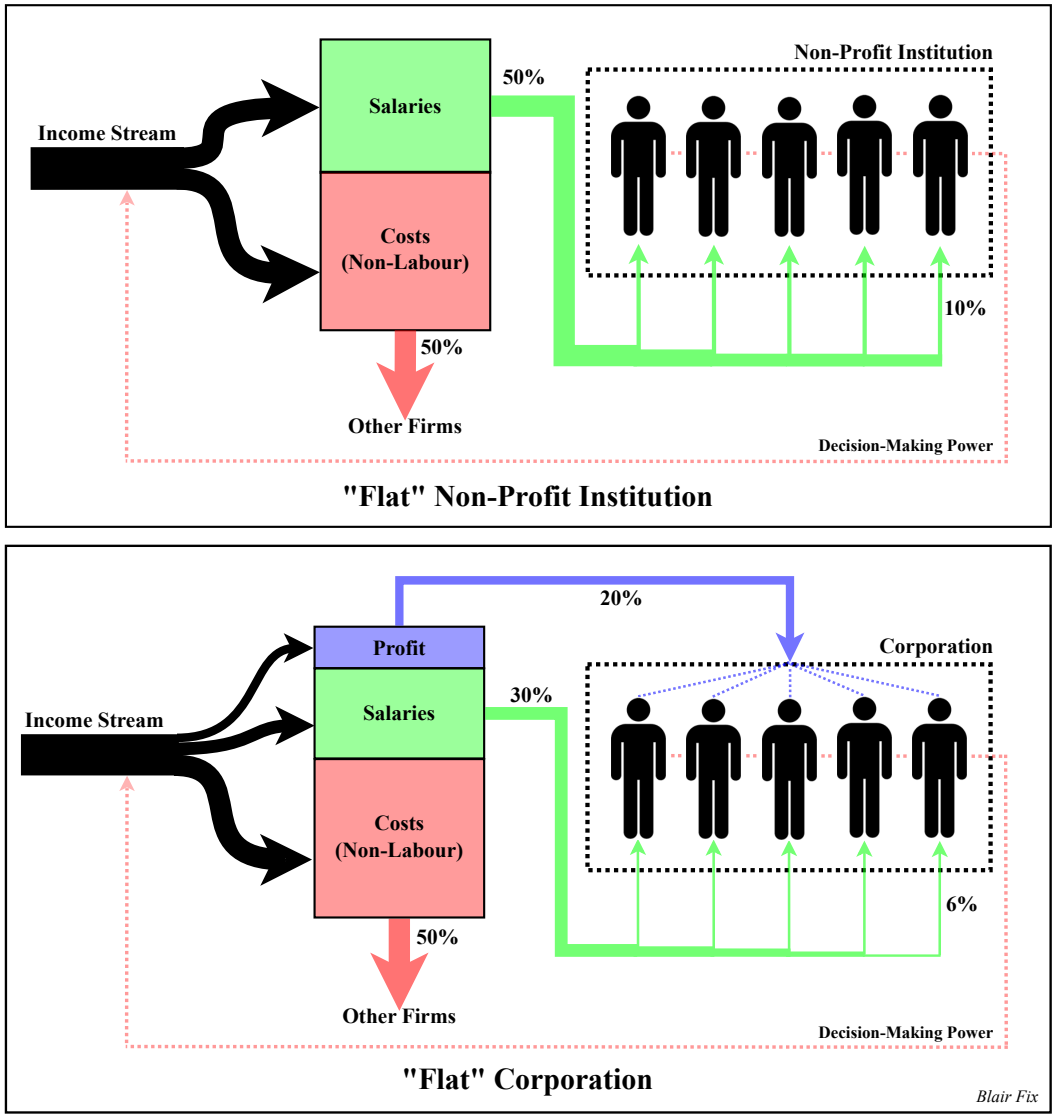

Figure 6: Flat Institutions

2.2 Flat Institutions

We now move on to institutions that include more than one person. We begin with non-hierarchical, or so-called "flat", institutions (Fig. 6). A flat institution is characterized by a complete lack of hierarchy. In its ideal form, this means that each individual has an equal say in all decision-making processes. Such radical equality seems to be possible only in small groups. As group size increases, it becomes increasingly difficult for people to arrive at consensus on all issues, and some form of hierarchy seems always to emerge.[21]

Our hypothetical, flat institution can either be operated as non-profit organization (i.e.: a cooperative), or as a flat corporation (with ownership divided equally among its members). In the former case, all income in excess of costs is allocated to salaries, while in the latter case, this income is split between profit and salaries.

As we did previously, we imagine a society populated only by such flat institutions. Again, we ask: what is the effect of a redistribution of income towards profit? This could occur two ways – either by non-profits deciding to become for-profit, or by for-profits increasing their markup (profit as a portion of total income).

In *neither* case does this change affect the ultimate control of the pre-existing income stream (which is always allocated equally to all individuals). However, the re-categorization of salaries into profit does have the effect of *pooling* income. For instance, having a group of 5 people control $100 000 in profit is different than having each of those 5 people control $25 000 in salaries. Pooling income allows for the possibility of a larger "investment" than would be possible otherwise.

A counter to this argument, however, is that the ability to pool income does not *require* profit. Indeed, the initial, undifferentiated income stream is the ultimate source of any pooled income. Thus, if a co-operative wishes to make a large purchase, it may simply divert more of its income stream towards "costs" and less towards salaries. The end result is the same.[22]

As we did with single-person institutions, we reach the conclusion that when profit only flows to flat institutions, it cannot serve to concentrate income.

[21] Michael Albert [1] offers theoretical ways of implementing a large-scale, non-hierarchical, industrial system by means of a nested array of direct democratic institutions. While interesting, we have no way of knowing if these ideas are possible (or practical), as they have never been implemented.

[22] It is interesting to note how language constrains our thinking in this situation. Profits are always "invested" while costs are simply money that was"spent".

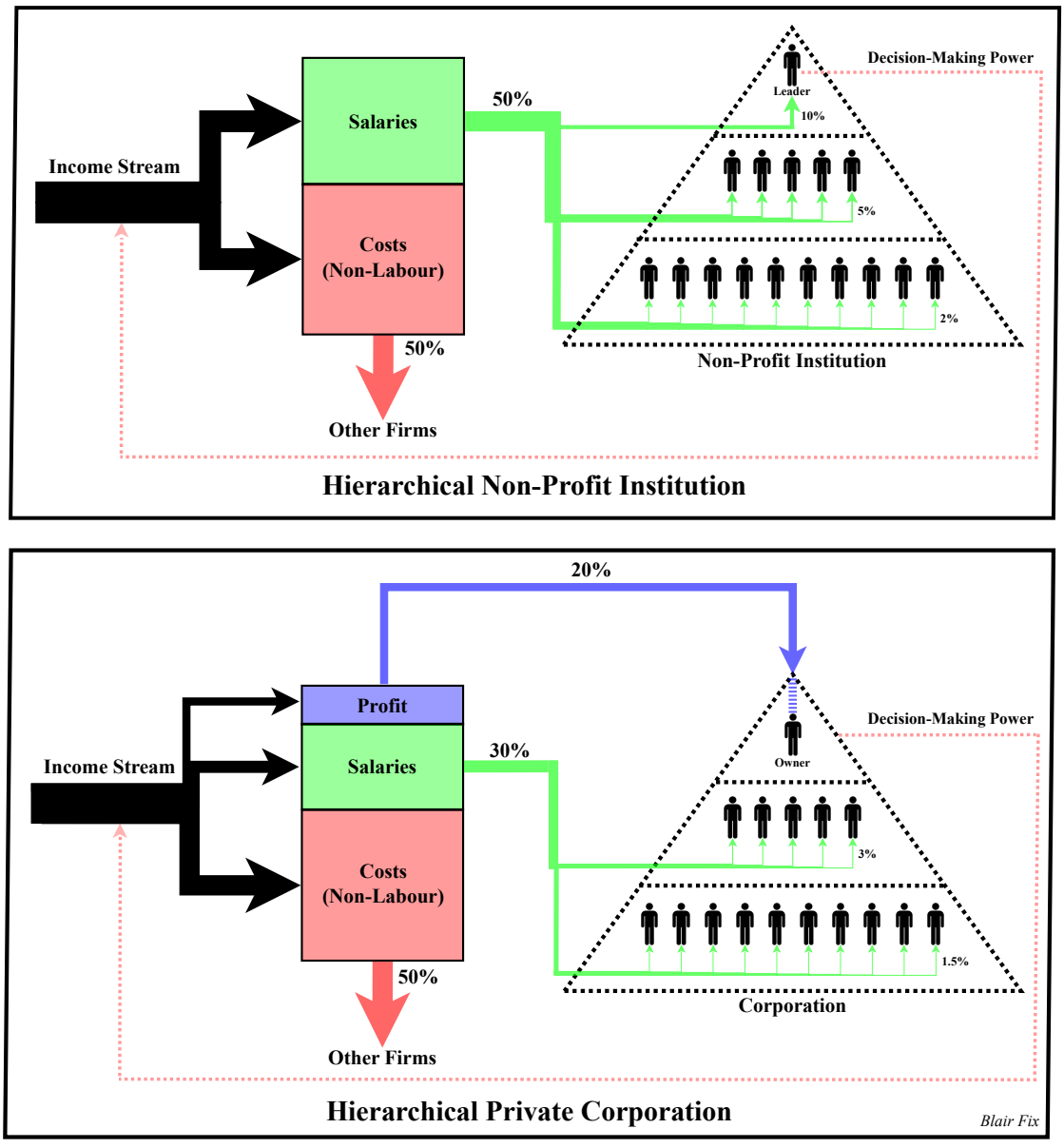

Figure 7: Hierarchical Institutions

2.3 Hierarchical Institutions

We now move on to hierarchical institutions (Fig. 7). Here we envision the quintessential hierarchy that is marked by a strict top to bottom chain of command, with all decision-making power ultimately residing at the top. We have two possible types of institution – the hierarchical non-profit and the hierarchical private corporation. A good real-world example of the former are state-owned companies like Fannie Mae or PetroChina, while large private companies like Cargill or Koch Industries are good examples of the latter.

Note that in both non-profit and for-profit examples, salaries are now distributed unequally. This is not a *requirement* of a hierarchical institution, but it is the *norm* (see Fig. 9 for an interesting empirical link between the size of a corporation and inequality of pay).

As before, we are interested in the effect of redistributing income towards profit, but now in a society populated entirely by hierarchical institutions. There are two possible scenarios. Firstly, a non-profit organization may become a for-profit, as when a state-owned company is privatized. Secondly, for-profit organizations could increase their markup (profit share of total income stream).

Unlike our previous examples, here *both* scenarios imply a concentration of income. As before, profit flows to the institution, but now control of the institution resides with a *small subset of people*. We can formalize this as follows.

We begin by dividing an income stream (I) into 3 categories: wages (W), profit (Π), and costs (C).

$$I = W + \Pi + C \tag{12}$$

Since all costs will eventually become the income stream of a different company, we ignore this term from now on.

Next, we calculate the average income of an *individual* owner (i_O) or *individual* worker (i_W) by dividing total profit and wages by the number of owners (N_O) and workers (N_W), respectively :

$$i_O = \frac{\Pi}{N_O} \tag{13}$$

$$i_W = \frac{W}{N_W} \tag{14}$$

By dividing (13) by (14) we can define the differential income (DI) of individual owners relative to individual workers:

$$DI_{\frac{O}{W}} = \frac{\Pi/N_O}{W/N_W} \tag{15}$$

Rearranging, we get the following:[23]

$$DI_{\frac{O}{W}} = \frac{\Pi}{W} \cdot \frac{N_W}{N_O} \tag{16}$$

Equation 16 tells us that any increase in total profit (Π), relative to the total wage bill (W), increases the differential income of owners. By itself, this finding is fairly banal – obviously a differential increase in profit should lead to an increase in the differential income of owners.

However, the interesting insight is that differential income of owners is proportional to the ratio of the number of workers to owners. This term can be thought of as a metric for the *degree of hierarchy* (H).[24]

$$\frac{N_W}{N_O} = H \tag{17}$$

In the limit of a flat institution, where all workers are also owners ($N_W = N_O$), H reduces to one. The more hierarchical the institution – the more workers relative to owners ($N_W > N_O$) – the greater H becomes. Putting (17) into (16), we get:

$$DI_{\frac{O}{W}} = \frac{\Pi}{W} \cdot H \tag{18}$$

To summarize, (18) tells us that hierarchy serves as a *magnifier* for the differential income of owners. If the H term is large, a relatively small increase in profit (relative to wages) can be magnified into an enormous increase in differential income. For instance, a medium-sized firm with 1000 employees and 5 owners gives an H of 200. Thus, a 2% differential increase in profit leads to a 400% increase in the differential income of owners!

[23] For equation 16 to be valid, it is crucial that workers and owners be *different* people. In flat and single-person institutions, this is not the case – workers and owners are the *same* people – meaning the equation is not applicable.

[24] There are many different ways of measuring hierarchy. One method is to count the number of distinct administrative levels within an organization [61]. Another technique is to use network theory to quantify the number of connections among nodes [44]. My approach here is very simplistic – I remove all layers except the hierarchy between owners and employees. While this is a gross simplification, I believe it provides useful insights.

2.4 Hierarchical Public Corporations

If we were undertaking this analysis at the turn of the 20th century, our work would be complete. At that time, the dominant business institution was the private company run by the "captain of industry". However, this form of business enterprise is now in the distinct minority, having long since been superseded by the public corporation. As Veblen aptly put it, this gave rise to the phenomenon of "absentee ownership" [62].

The public corporation creates a distinct separation between management and ownership (Fig. 8). We represent this by placing the chief executive officer (an employee) at the top of the hierarchy, while owners (shareholders) exist outside the hierarchy. This institutional arrangement has the potential to greatly dilute the ownership role. Berle and Means famously argued that management, rather than owners, effectively control the operations of public corporations [5]. We represent this graphically, in Figure 8, by turning stockholders into a mass of undifferentiated little people. Each individual owner has little to no say in how the company is run.

What effect will this have on the differential income of owners? We can investigate by returning to our hierarchy equation (17). Here, H can only serve as a magnifier of differential income if the number of employees is greater than the number of owners. We can use Walmart as an example. In 2012, Walmart had 2.2 million employees and 3.3 billion (3, 314 million) shares outstanding.[25] In the hypothetical situation in which every single share is owned by a different person, our H term becomes:

$$H = \frac{N_W}{N_O} = \frac{2.2}{3,314} = 0.0007 \tag{19}$$

Thus, if Walmart stock were dispersed to the maximum level possible, it becomes almost impossible for profit to increase the differential income of owners. Looking at equation 18, total profit would need to be more than 1500 times the total wage bill for the average owner to earn more than the average worker. Clearly such stupendously large profits are unlikely.

In a world populated only by public corporations with highly dispersed stock ownership, we must conclude that increases in profit are incapable of concentrating income in the hands of owners. But in the world that actually exists today, how evenly distributed is stock ownership?

Again, we can return to Walmart. While the existence of 3.3 billion shares gives the potential for many owners, in *actuality*, over 50% of these

[25] Walmart stats are from COMPUSTAT database.

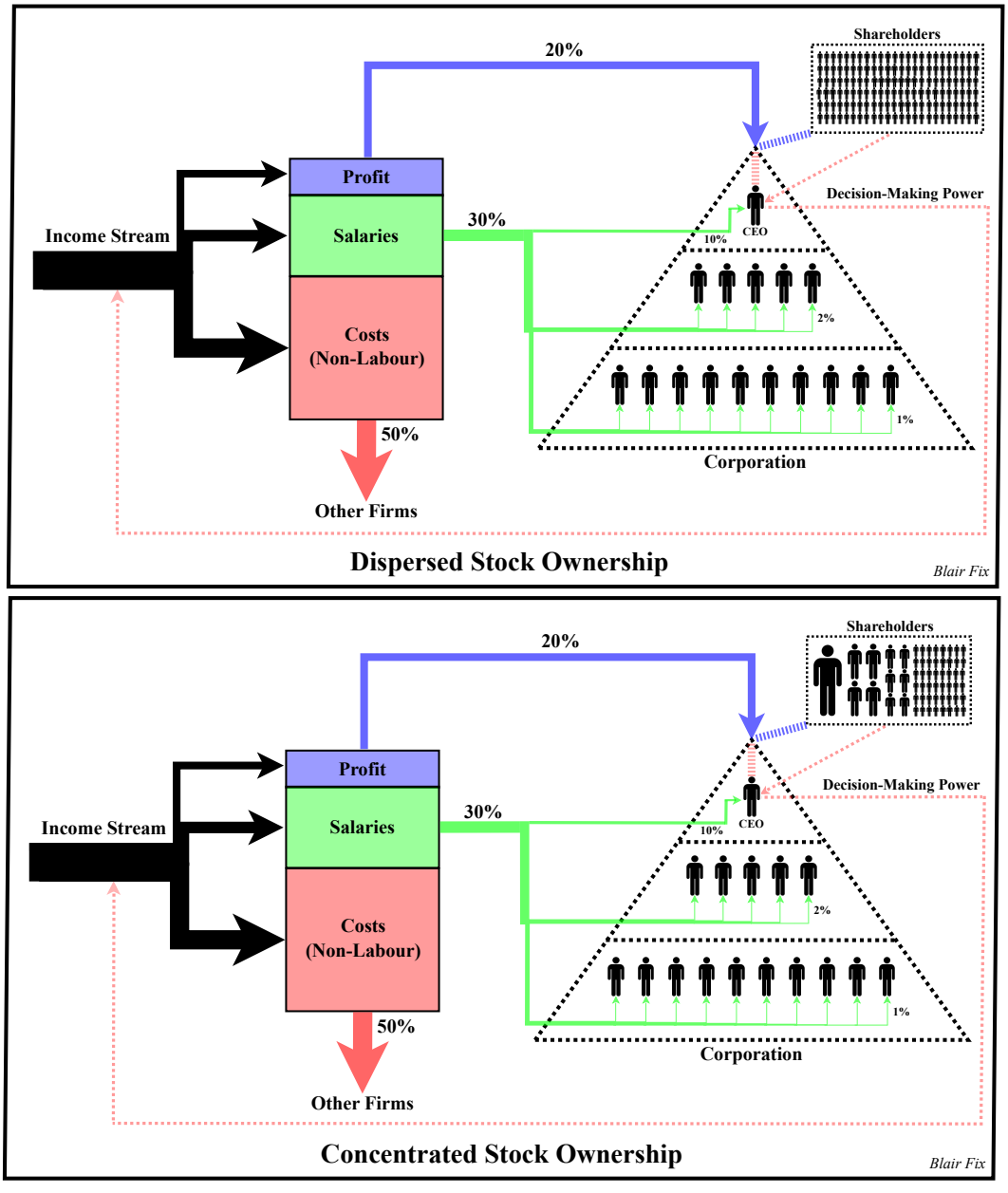

Figure 8: Hierarchical Public Corporations

shares are owned by the Walton family [19]. Under New York Stock Exchange rules, this makes Walmart a "controlled" company. Referring back to our hierarchy index H, this means that the number of *effective* Walmart owners is actually very small.[26]

Of course, this is just one example. What we want to know is the concentration of stock ownership *in general*. Looking at the US in 2010, Edward Wolff finds that 91.2% of all business equity was owned by the wealthiest 10% of the population [67]. Moreover, this figure has been consistent (to within 3%) over the last 30 years. Studies carried out on a global level show similar levels of concentration [28,64]. Thus, it would seem that in the world we inhabit, the number of effective owners is vastly smaller than the number of workers, meaning our H term can remain a multiplier of differential income.

2.5 Profit & Hierarchy

My reason for the preceding conceptual analysis was to better understand the importance of the redistribution of income towards profit. We wanted to understand how introducing profit (or increasing it) would change society. Our finding was that by itself, profit was not particularly interesting – its function seemed to depend entirely on the institutional context.

We defined profit simply as income that flowed to owners of institutions. But since anyone, in principle, can own an institution, this told us nothing. Indeed, when ownership is distributed equally, we concluded that redistribution towards profit can have *no effect on society*! It is only when coupled with *hierarchy* that profit becomes interesting. Hierarchy brings about a vast reduction in the number of owners, relative to workers, meaning that increases in profit necessarily concentrate more income in the hands of the few.

The reason we were interested in profit was because we discovered a significant correlation between redistribution towards profit and growth in material throughput (Section 1.5). There is, of course, the possibility that this correlation is completely spurious. However, for the present time, let us assume that it is not. Rather, we choose to assume that this correlation implies some sort of causative relationship – even if it is circular feedback. Given this assumption, I hypothesize that:

[26] According to the Wikipedia entry for the Walton family, 6 of the family members control most of the family fortune.

Hypothesis A: Differential increases in profit *must* have a material effect on society.

Furthermore, given the results of our conceptual institutional analysis, it follows that:

Hypothesis B: A differential increase in profit can *only* have a material effect if it is coupled with hierarchy.

Combining (A) and (B), gives hypothesis (C):

Hypothesis C: Hierarchy *must* have a material effect on society.

To restate, by combining the logical implications of both our empirical and conceptual investigations, we have derived hypothesis (C). The claim is that we ought to be able to connect hierarchy with some measurable, material quantity. In the next section I outline a methodology for making such a connection.

3 The Material Effects of Hierarchy

In order to empirically test hypothesis (C), we must be able to measure both hierarchy and some sort of material change. On the material side, it seems logical to continue to use energy consumption, since we have argued that it is the most meaningful measure of growth in biophysical throughput. On the hierarchy side, the choice is more difficult. Below, I outline a few options.

3.1 Measuring Global Hierarchy

We begin by noting that our hierarchy term H was formulated within the context of a single corporation. Simply put, it told us the ratio of the number of workers to the number of owners. How can we generalize this method in order to create a "global hierarchy" (H_g) index for society at large? (Note: I use the term "global" in the sense of the entire system in question – a sector, nation, region, etc. – not the entire "globe".)

One method would be to compute H for every single existing corporation, and then average the results (perhaps with some sorting of weighting by size). However, the immediate problem with this approach is that there

exists no exhaustive list of employment and ownership data for all corporations. Ownership data of any kind is difficult to come by – especially when it comes to private corporations.

Because of this, I propose the following assumptions:

Assumption 1: Within any given company, the number of owners grows *much* more slowly than the number of employees. Thus, we can treat the number of owners as essentially fixed over time.

Assumption 2: For any given company, growth in the number of employees implies a growth in the degree of hierarchy (H).

There is good evidence to support the validity of this assumption. For instance, Turchin & Gavrilets study six historical empires and find a strong relationship between the population size of the empire and its hierarchical complexity (where hierarchical complexity is quantified by the number of distinct administrative levels) [61]. Furthermore, the stratification of pay between *management* and average workers shows correlation with company size (Fig. 9). It is stratification, in general, that is the hallmark of hierarchy. Given that other measures of hierarchy seem to increase with institutional size, it seems reasonable to assume that owner-employee hierarchy does as well.

Given these assumptions, an elegant way of measuring the global degree of hierarchy would be to first rank ($r = 1, 2, 3, ...$) companies by employment size (E_r) and then compute the number of companies (N) needed to reach some critical portion (λ) of total employment (E_{Total}):

$$\sum_{r=1}^{N} \frac{E_r}{E_{Total}} = \lambda \quad \Longrightarrow \quad H_g = 1/N \tag{20}$$

The smaller the value of N, the greater our measure of hierarchy, and vice versa. Maximum hierarchy occurs when $N = 1$, in which the vast majority of people are employed by a single corporation. Again, the problem with this method is lack of data. If λ is large (ie: 80%), the value for N could potentially be huge, and we would be unable to find data for the required number of corporations.

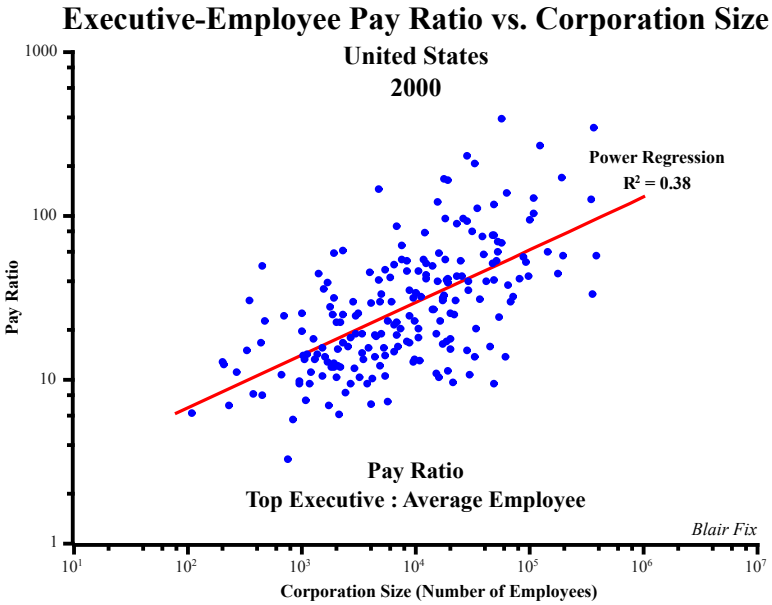

Figure 9: Stratification of Management Pay

Sources: Top executive compensation is from Execucomp, series TOTAL CURR. Compensation per average employee calculated by dividing COMPUSTAT labor and related expense (DATA42) by number of employees (DATA29).

In order to work around this lack of data, a simple solution is to reverse the unknowns. In equation 20, λ is held constant while we solve for N. The reverse is to hold N constant and solve for λ. The result is the portion of total employment held by the top N firms (where N is an arbitrary number chosen based on the availability of data). Now λ becomes our metric for H_g:

$$H_g = \lambda = \sum_{r=1}^{N} \frac{E_r}{E_{Total}} \tag{21}$$

This can be stated more simply by creating a term for the aggregate employment of the top N firms (E_{TopN}). This gets rid of the sum notation, and (21) becomes:

$$H_g = \frac{E_{TopN}}{E_{Total}} \tag{22}$$

To reiterate our line of thinking, we assume that the larger a single

corporation gets, the greater its internal degree of hierarchy. From this, we generalize that the greater the portion of total employment held by the Top N firms, the greater the global degree of hierarchy.

3.2 Hierarchy and Energy: Empirical Results

We are testing the hypothesis that hierarchy, now quantified by H_g, must have a material effect on society. To clarify, this does *not* assume one-way causation – we merely want to establish a long-term connection between changes in hierarchy and some sort of material change in society. Because of its theoretical importance, we continue to use energy as our material metric.

However, in this section, we now switch to *primary* energy accounting, rather than *useful work*. Although useful work is ideal (because it separates wasted from usable energy), its use is limited because it has only been calculated for a handful of countries[27] and data exists only at the national level (ie: no data for sub-sectors of the national economy).

Rather than useful work per capita, here we use *primary energy consumption per labour hour* (PE_{hr}). To state formally, we are looking to find correlation over time between PE_{hr} and H_g:

$$H_g \iff PE_{hr} \tag{23}$$

Because of the importance of energy to *all* activities, PE_{hr} can be regarded as rough estimate for the total material throughput per labour hour.[28] If we find correlation between the two terms in (23), this means that changes in hierarchy are linked with changes in material throughput.

When this methodology is carried out over two sub-sectors of the US economy – Industry and Services – the results are striking (Fig. 10 & 11). We see that our metric for hierarchy is *highly* correlated with changes in material throughput, thus supporting hypothesis (C).

We can garner further supporting evidence if we apply this methodology to an international level. Since international data is more sparse, we have to limit analysis to the portion of total domestic employment controlled by the top 10 corporations (Fig. 12). Again, there is excellent correlation between this metric (H_g) and primary energy consumption per capita.

These are certainly startling results, but what do they mean? Since political economy has paid relatively little (to no) attention to energy, this

[27] To date: Austria, Japan, United Kingdom, and the United States.

[28] Again, using useful work per labour hour would be more accurate, but data does not exist at the sectoral level.

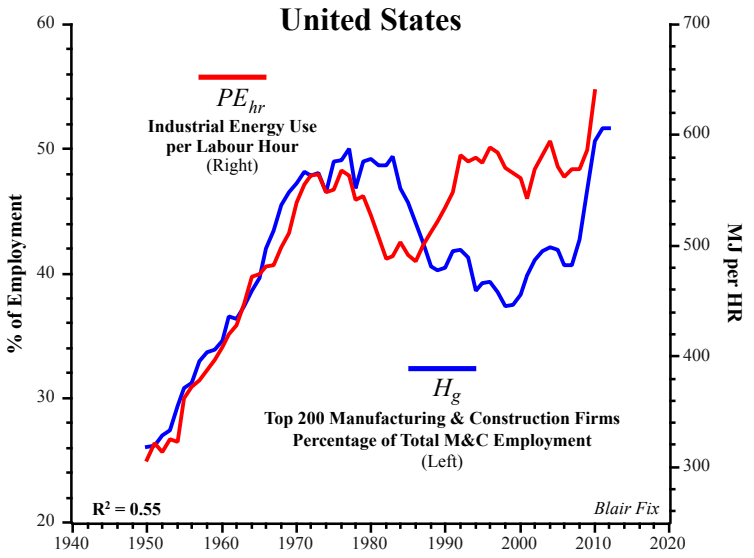

Figure 10: Hierarchy & Energy in Industry

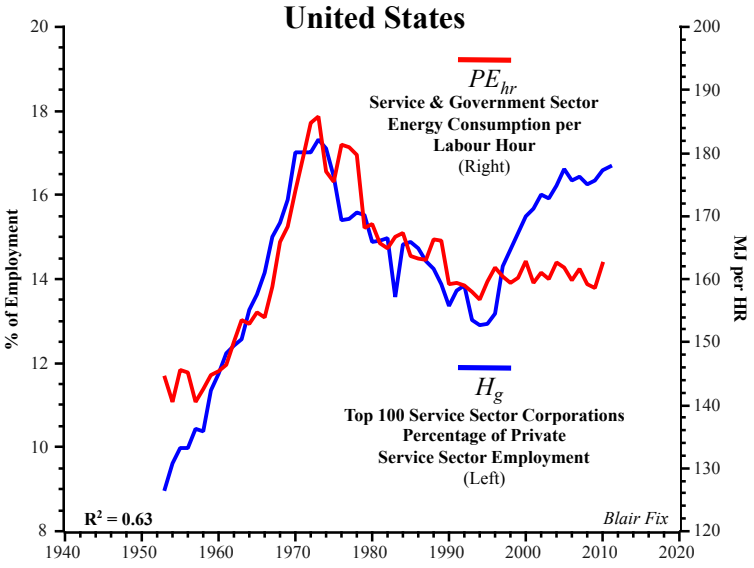

Figure 11: Hierarchy & Energy in Services

Sources: See Appendix

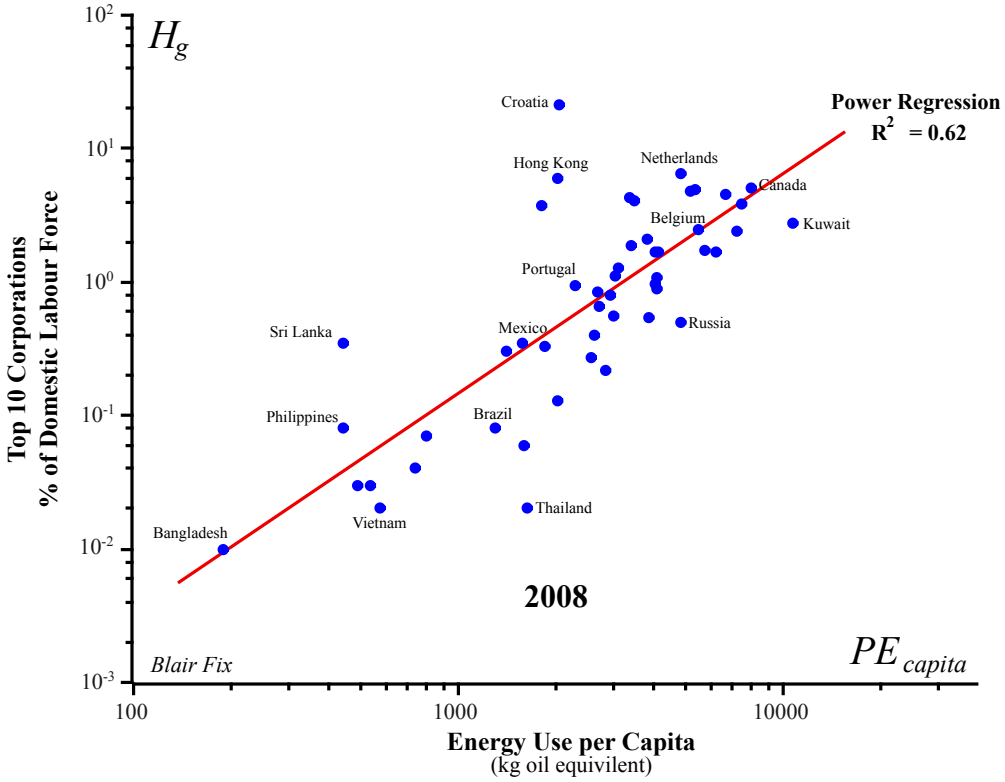

Figure 12: Hierarchy & Energy Internationally

Sources: National energy-use per capita and total labour-force data is from the World Bank (using indicator codes EG.USE.PCAP.KG.OE. and SL.TLF.TOTL.IN, respectively). Employment of top 10 corporations is from COMPUSTAT Global Fundamentals (series EMP).

canon of literature does not offer many theories to explain our observations. My own theories, which are tentative, are discussed below.

4 Discussion

The question before us is: why are changes in corporate concentration (hierarchy), growth in material throughput, and income redistribution towards profit all connected?

The first possibility is that these connections are merely coincidental. In

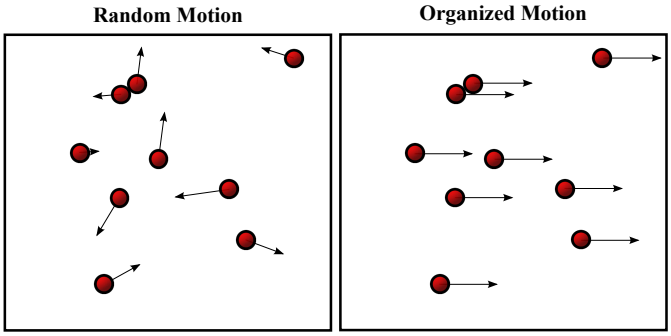

Figure 13: Creating Organization

my opinion, however, the robustness of the empirical evidence makes this option relatively implausible. Therefore, the remaining possibility is that that there is some sort of fundamental connection between these phenomena.

My own explanation hinges on a hypothesized connection between the growth in material throughput and a *required* increase in organizational complexity. I begin by building on Chaisson's thesis that the energy flow through a system (per unit time and mass) can be used as a measure of its complexity [10]. This measurement has also served as our indicator of growth in material throughput. Thus, I posit a two-way relationship between material growth and complexity:

> **Hypothesis D**: For a social-system to grow, it must become more complex. For a social-system to become more complex, it must increase material throughput.

I further hypothesize that:

> **Hypothesis E**: Increases in complexity require increases in *coordination* among social actors.

This link between coordination and complexity is crucial. I define *coordination* as the ability to organize or integrate diverse elements in a harmonious operation. A simple representation of organization is given in Figure 13. We can think of unorganized activity much like the random motion of particles in a gas (left). Coordination allows these particles to suddenly move in one direction. This does not simply happen by chance – entropy

forbids it. There must be some kind of mechanism to produce these changes. In this case, it could be that some external force set the right hand container in motion, giving all the particles the same rightward motion.[29]

We can use Figure 13 as a metaphor for organization among humans – it does not happen by chance.[30] In order for a social system to become more complex, specific mechanisms must foster coordination among people who were previously uncoordinated.

4.1 Social Coordination

How are humans able to coordinate their actions? I propose that all types of coordination can be reduced to a combination of the following mechanisms:

Mechanisms of Coordination

1. Conscious Consensus
2. Unconscious Consensus
3. Coercion

We begin with conscious consensus. I reserve this term for all unanimous decisions made by a group about problems that have been clearly *articulated*. In this situation, a group must consciously chose among many possible courses of action, with the final decision being made only when all individuals agree. This method of coordination is difficult, but rewarding. It requires all individuals to think in a like-minded way, or at least be willing to compromise with different-minded people. In small groups, this mechanism is highly effective. It fosters solidarity and is uplifting to the human spirit. However, as group size grows, it becomes increasingly difficult.[31]

Unconscious consensus provides a more powerful tool for organizing larger groups, precisely because humans coordinate without consciously

[29] In addition to this rightward motion, the particles would still have random motion associated with heat. Fig. 13 ignores this motion.

[30] Interestingly, there is a long history, in economics, of using statistical mechanics as a basis for models of the economy. See Mirowski [43] for a discussion of the perils of this approach.

[31] Anthropologist Robin Dunbar finds strong correlation between the average group size of primates and the size of their neocortex (in relation to the rest of the brain) [20]. His hypothesis is that large brains arise from the need to keep track of numerous social interactions. From this finding, it follows that the brain's computational ability places an effective upper bound on the size of group that can operate by means of conscious consensus.

agreeing to do so. This mode of organization can essentially be called culture, but I use this term to mean any *habitual* behavior shared between a group of people. The key to this mechanism is that it stems from repetition, meaning it is inherently static (or at the very least, slow to change). For instance, millions of people celebrate Christmas each year, without ever agreeing consciously to do so. What culture is incapable of, however, is abrupt change. It is inconceivable that millions of people, having celebrated Christmas all their lives, would suddenly *all* cease to do so *at the same time*.

Both conscious and unconscious consensus, as the names suggest, require unanimous agreement to function. If an individual does not want to cooperate, these mechanisms offer no recourse. Coercion offers a way out of this conundrum by giving a means of compelling individuals to cooperate. The essence of coercion is the formation of some sort of power dynamic that allows one group of people (or individual) to bend another group (or individual) to its will. Coercion is a very powerful tool for coordinating large groups of people. Indeed, the mega-projects of antiquity almost always made use of massive pools of slave labour –what Lewis Mumford aptly called "mega-machines" [46]. The downside of coercion is that it is highly destructive to the human spirit. Too much coercion inevitably leads to social unrest.

4.2 The Path of Least Resistance

Most successful attempts at organizing large groups of people make use of a mixture of these 3 mechanisms. The ubiquity of hierarchy in all aspects of modern life seems to suggest that it is the path of least resistance for organizing great swaths of people for a specific purpose. Its essential innovation can be summed up as follows – conscious consensus at the top, coercion at the bottom, and unconscious consensus legitimizing the chain of command.

Hierarchy uses conscious consensus, but in a highly restrictive manner. Within a large organizational group, hierarchy functions to shrink the size of the deliberative body, potentially down to a single person. Those at the top form a consensus, which is then applied to the group as a whole. This leveraging effect operates both on a coercive and unconscious-consensus level. Coercion can take all sorts of forms, but the point is that subordinates carry out the will of a superior when they are consciously aware that they would rather not.

Forced labor serves as the best example of coercion. Yet, as tasks become more complicated, coercion becomes less effective. Thus, blatant coercion is usually only applicable to the lower echelons of an organization. The middle echelons cannot be coerced because their jobs are best performed if they feel

they have a vested interest in the organization. Here, unconscious consensus is essential. Fostering the appropriate organizational culture will legitimize the authority of superiors. Thus, orders are given, but they are followed habitually, or even gladly [53].

Despite the ubiquity of the modern multi-national corporation, neoclassical theory almost completely ignores the role of hierarchy in organizing production. Instead, the focus is usually on "market exchange". Indeed, the reader might be wondering why I have left out "the market" as a mechanism for coordination. My answer is to propose that the market is not an organization mechanism at all; rather, it is the outward manifestation of a set of deeply held *beliefs* about the quantitative equivalence of qualitatively different phenomena. The market is a manifestation of capitalist *culture*.

4.3 The Market as Culture

My assertion is that the "market" is a cultural mechanism for legitimizing hierarchy. In order to make this argument, I begin by investigating the historical cultural mechanisms that have assumed this legitimizing role in the past. Religion, it seems, has been the major player.

Peter Turchin argues that it is not coincidental that both the major world religions and the first large empires emerged during the same era (the Axial Age, 800–200 BC) [60]. Religion is highly effective at rationalizing social status, and thus legitimizing hierarchy. From ancient Egypt to feudal Europe, rulers frequently appealed to divinity in order to legitimize their power.[32]

In modern capitalist society, the religions of antiquity have lost much of their potency. However, the modern social order is rationalized by a secular religion: the belief in the free market. Despite ubiquitous assertions to the contrary, it is important to understand that the the "market" is not a "thing" – it is a set of beliefs [30]. The most important is the following *unstated*, and *habitual* consensus:

The Free Market Consensus

Anything that can be "owned" may be reduced to a single, abstract quantity called a *price*. If prices are equivalent, an ownership exchange is culturally defined as being *reciprocal*.

This mass belief in quantitative reciprocity is a stunning cultural innovation. Economists typically focus on how this belief facilitates barter.

[32]Religions do not just rationalize the power of the ruling class; they often rationalize an entire caste system (Hinduism in feudal India, Christianity in feudal Europe).

However, I argue that its more important effect is to facilitate the *legitimization of hierarchy* [34].

We start with the assertion that a monetary transaction is a *sacred act* that can *never* be unfair. This follows directly from the "free market consensus". If we believe in the quantitative equivalence of prices, unfair market exchange lies outside the realm of possibility.[33] In many ways, this observation is banal. If it were not true, the price-system simply would not exist. However, it has very important implications for hierarchy.

In capitalist society, hierarchical relations are rationalized by appealing to the reciprocity of monetary transactions. Because monetary transactions are culturally-sanctioned as reciprocal, the possessor of large sums of money (i.e. *capital*) has the power to mobilize and control human labor in way that is *defined as reciprocal*.

It is difficult to "de-familiarize" ourselves from this belief in reciprocity. But the chain of beliefs is no different, in principle, than divine kingship:

Divine Kingship

1. God is the ultimate authority.
2. Kings are ordained by God.
3. Kings are legitimate holders of power.

Free Market Consensus

1. Monetary exchange is reciprocal.
2. Capitalists exchange money for "ownership".
3. Owners are legitimate holders of power.

Capital, it would seem, has replaced divine status is a way of legitimizing authority. Furthermore, I argue that capital has proved much more effective at legitimizing authority than any other cultural mechanism. The proof of this exists in our language, by the great esteem held by words that describe capitalist power. While kings, states and empires *tax* and *spend*, capitalists *invest*.

[33] As Hornborg notes, in order to assert that an exchange is unfair, we must appeal to something outside of market prices [35]. Marxists do this by appealing to labour-time [21]. Hornborg suggests a variety of biophysical metrics. The point is that in order to concede unfairness, we must appeal to a belief outside of the free market consensus.

4.4 Profit: The Fountainhead of Legitimacy

Capital, unlike appeals to divinity, has a finite magnitude that is *depleted* when power is wielded. This presents a problem: unless capital can be renewed, it will be an ephemeral source of power. Herein lies the great necessity of profit.

Capital is not *spent*, it is *invested*. Money that is spent is gone for ever, but investment has the magical property of making capital self-renewing, because it confers the right to a pecuniary return: *profit*. By investing capital, a capitalist gains culturally sanction control over human labor, but also gains the potential[34] for this control to *accumulate* [48].

In Section 2.3, I argued that the differential accumulation of profit (relative to wages) was *magnified* by hierarchy. It is the coupling of profit and hierarchy that allows owners to accumulate power. This is important, because it confers the ability to organize still larger social hierarchies *without* the appearance of coercion. Stated another way, profit has the potential to *immortalize* the legitimate hierarchy-building capacity of an owner, and to allow the culturally-sanctioned accumulation of this capacity.

4.5 Rethinking Profit

We are now in a position to synthesize our empirical results and put forward a chain of causation linking profit, hierarchy and energy. I propose four steps that can either function to stimulate growth or to sabotage it.

Growth Mode

1. Income is redistributed *towards* profit.
2. This redistribution, magnified by existing hierarchy, serves to concentrate income in the hands of a small subset of society – capitalists. When this income is reinvested, it allows capitalists to increase the span of their control and thus increase the scale of organizational hierarchy
3. This increase in hierarchy increases the coordination capacity of society.
4. Increased coordination allows increases in material throughput and complexity.

[34] I say "potential", because returns on capital are never guaranteed. Some capitalists lose everything.

Sabotage Mode

1. Income is redistributed *away* from profit.
2. This redistribution, magnified by existing hierarchy, serves to dilute income that was once concentrated in the hands of a small subset of society – capitalists. This dilution sparks fear and capitalists cease to reinvest existing profit. This decreases their span of control and thus decreases the scale of organizational hierarchy
3. This decrease in hierarchy decreases the coordination capacity of society.
4. Decreased coordination causes a decrease in material throughput and complexity.

I think of these steps as a causal chain, but likely one that is *not* linear. For instance, there is no reason that the causal chain could not *begin* with a material constraint that then induces a decrease in hierarchy and a redistribution away from profit. For instance, the 1970s plateau in both energy consumption and hierarchy (shown in Fig. 10 & 11) aligns conspicuously with both the peak in US oil production (circa 1970) and the transition from exponential to linear growth in global oil production.

5 Conclusions

The belief that profit is an incentive mechanism responsible for stimulating economic growth holds little water when examined carefully. The problem is that incentive mechanisms have always played a role in shaping human behavior – indeed, all animal behavior. Why should the desire for profit be any more powerful than lust, hunger, or the desire for power? These incentives have been around for millennia, but growth has not.

Instead of playing an incentive role, I argue that profit is a means for concentrating power, a tool that legitimizes the ability of capitalists to coordinate great swaths of humanity by means of hierarchical business organizations. This coordination, I have argued, is what facilitates growth.

Whether or not this process is good for humanity is quite another matter. Ecological economists have thoroughly critiqued the notion that growth in throughput equates with growth in human well-being [18,37,40,63]. Furthermore, hierarchy necessarily implies inequality (sometimes in pay, but always in status and power). This clashes with the innate desire among

humans (and other primates [8]) for egalitarianism. Perhaps this explains why the vast majority of humans do not like their jobs.[35]

The greatest weakness of the approach that I have proposed is the assumed link between hierarchy, coordination, and complexity. What is needed is a method for comparing my measure of hierarchy (H_g) with a metric of *organizational complexity*. In addition, a better understanding of the relationship between complexity and material throughput is required – one that moves beyond the recursive nature of my own treatment.

Despite these weaknesses, this approach has the great advantage of being grounded in empirical observations. Both Marxist and neoclassical theories do the opposite – they begin with a set of logical axioms from which their entire theoretical edifice is based. Rarely, if ever, are these logical postulates subjected to empirical tests. The theory that I have proposed, in contrast, is build on relatively few theoretical assumptions. Rather, it *begins* with empirical evidence and proposes a logical framework for explaining this evidence

The challenge of consilience, laid out by E.O. Wilson [66], is to make the social sciences compatible with the natural sciences. At the present time, many economic theories clash with the laws of physics. It is clear that economics, not physics, must be reformed. The task of the forward-thinking social scientist is to formulate new theories that are consilient with the modern natural sciences. My hope is that the approach proposed in this paper is a step in the right direction.

[35] A 2013 Gallup poll found that only 13% of the global workforce was "engaged" in their job, while 27% were "actively disengaged" and 63% were "not engaged" [23].

Appendix: Sources for Figures 10 & 11

Data for Corporate Concentration

Corporate Employment

Uses DATA29 (Employees) series from COMPUSTAT database via WRDS. Manufacturing and Construction sector is defined as SIC codes between 1520 and 3999. Service sector defined as SIC codes between 4000 and 8999.

Total Sectoral Employment

Data is from US Bureau of Labor Statistics. Series IDs:

Construction	CES2000000001
Manufacturing	CES3000000001
Services (Private)	CES0800000001

Energy Consumption per Labour Hour

Energy

Sector energy consumption is from Energy Information Agency, Table 2.1a: *Energy Consumption Estimates by Sector*. However, based on the MuSIASEM approach [26], the EIA categories are reorganized (Fig. 14).

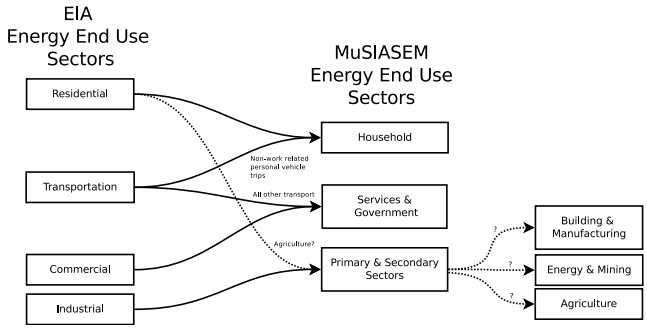

Figure 14: Recategorizing Energy Consumption

All energy from the Transportation sector is allocated to the service sector, *except* energy for non-work related, personal vehicle trips. Data

for non-work related vehicle mile trips (as a percentage of total VMT) comes from the 2009 National Household Travel Survey, Table 6. Data between points is interpolated linearly. Data prior to 1969 is extrapolated linearly from 1969-83 trend.

Data for personal vehicle energy consumption for the period 1970-2010 is derived from numerous editions of the EIA *Annual Energy Outlook* using Light-Duty Vehicle energy consumption. Data for the period 1949-69 is derived from passenger car & 4-tire vehicle fuel consumption data from the Department of Transportation, Table VM-201A (Note: the category 4 tire vehicles is introduced in 1966 at a non-zero value. Data prior to 1966 is estimated by exponential extrapolation).

Labour Hours

Uses Bureau of Economic Analysis *Persons Engaged in Production Series* – Table 6.8A (1929-48), Table 6.8B (1948-87), Table 6.8C (1987-2000), & Table 6.8D (2000-2011). All values are indexed to Table 6.8C and multiplied by 40 $hr/week \times 52.1775\ weeks/year$.

Note that service sector is here redefined to include government. This is because energy statistics do not distinguish between private and public consumption. See Figure 15 for mapping of sectors onto NAIC categories.

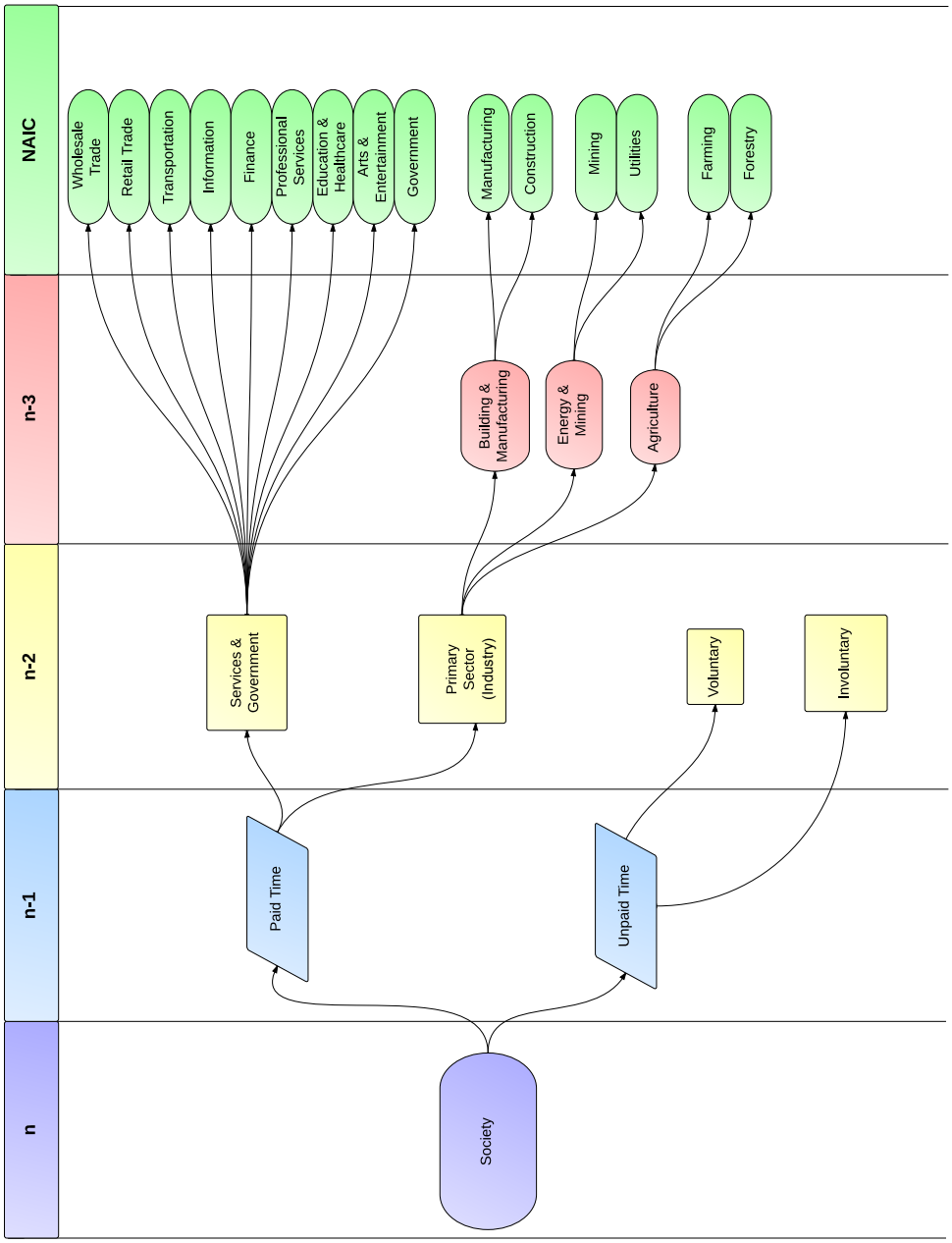

Figure 15: NAIC Mapping

References

[1] Albert, M. *Parecon: Life After Capitalism*. Verso, 2004.

[2] Arrighi, G. *The long twentieth century: Money, power, and the origins of our times*. Verso Books, New York, 1994.

[3] Ayres, R., and Warr, B. Accounting for growth: the role of physical work. *Structural Change and Economic Dynamics 16*, 2 (2005), 181—209.

[4] Ayres, R., and Warr, B. *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*. Edward Elgar Pub, Northampton, MA, Apr. 2009.

[5] Berle, A. A., and Means, G. G. C. *The modern corporation and private property*. Transaction Books, 1932.

[6] Brennan, J. A shrinking universe: How concentrated corporate power is shaping income inequality in canada, 2012.

[7] Brenner, R. *The economics of global turbulence: the advanced capitalist economies from long boom to long downturn, 1945-2005*. Verso Books, New York, 2006.

[8] Brosnan, S. F., and de Waal, F. B. M. Monkeys reject unequal pay. *Nature 425*, 6955 (Sept. 2003), 297–299.

[9] Bureau of Labor Statistics. Frequently asked questions about hedonic quality adjustment in the CPI, 2010.

[10] Chaisson, E. J. *Cosmic evolution: The rise of complexity in nature*. Harvard University Press, Cambridge, Mass., 2002.

[11] Cleveland, C., Costanza, R., Hall, C., and Kaufmann, R. Energy and the US economy: a biophysical perspective. *Science 225*, 4665 (1984), 890—897.

[12] Cleveland, C., Kaufmann, R., and Stern, D. Aggregation and the role of energy in the economy. *Ecological Economics 32*, 2 (2000), 301—318.

[13] Cochrane, D. Death grip: Scapegoating the subprime loser. *SCAPEGOAT Architecture/ Landscape/Political Economy*, 00 (2010), 6–8.

[14] Cochrane, D. T. Castoriadis, veblen, and the power theory of capital. Aarhus University Press, 2011, pp. 89—123.

[15] Cohen, A. J., and Harcourt, G. C. Retrospectives: Whatever happened to the cambridge capital theory controversies? *Journal of Economic Perspectives* (2003), 199—214.

[16] Cottrell, F. *Energy & Society (Revised): The Relation Between Energy, Social Change, and Economic Development*. AuthorHouse, Bloomington, Nov. 2009.

[17] Debeir, J. *In the servitude of power : energy and civilization through the ages*. Zed Books, Atlantic Highlands, N.J., 1991.

[18] Douthwaite, R. *The growth illusion : how economic growth has enriched the few, impoverished the many, and endangered the planet*. New Society Publishers, Gabriola Island, B.C., Canada, 1999.

[19] Dudley, R. Wal-mart board seen at risk of losing independent voices. *Bloomberg* (June 2013).

[20] Dunbar, R. I. Neocortex size as a constraint on group size in primates. *Journal of Human Evolution 22*, 6 (1992), 469—493.

[21] Emmanuel, A., and Bettelheim, C. *Unequal exchange: A study of the imperialism of trade*. Monthly Review Press New York, 1972.

[22] Friedman, M. The social responsibility of business is to increase its profits. *New York Times Magazine* (Sept. 1970).

[23] Gallup. State of the global workplace: Employee engagement insights for business leaders worldwide. Tech. rep., 2013.

[24] Garrett, T. J. No way out? the double-bind in seeking global prosperity alongside mitigated climate change. *Earth System Dynamics 3*, 1 (Jan. 2012), 1–17.

[25] Georgescu-Roegen, N. *The entropy law and the economic process*. Harvard University Press, Cambridge, Mass., 1971.

[26] Giampietro, M., Mayumi, K., and Sorman, A. *The Metabolic Pattern of Societies: Where Economists Fall Short*. Routledge, New York, Nov. 2011.

[27] Giampietro, M., Mayumi, K., and Sorman, A. *Energy Analysis for a Sustainable Future: Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism.* Routledge, New York, Oct. 2012.

[28] Glattfelder, J. B., and Battiston, S. Backbone of complex networks of corporations: The flow of control. *Physical Review E 80*, 3 (2009), 036104.

[29] Graeber, D. *Debt: The First 5,000 Years.* Melville House Pub, New York, 2010.

[30] Gudeman, S. *Economics as culture: models and metaphors of livelihood.* Routledge & Kegan Paul London, 1986.

[31] Hall, C., and Klitgaard, K. *Energy and the wealth of nations: understanding the biophysical economy.* Springer, New York, 2011.

[32] Harvey, D. *The enigma of capital: and the crises of capitalism.* Oxford Univ Pr, 2010.

[33] Hirsch, R. Mitigation of maximum world oil production: Shortage scenarios. *Energy policy 36*, 2 (2008), 881—889.

[34] Hornborg, A. *The power of the machine: global inequalities of economy, technology, and environment*, vol. 1. Altamira Pr, 2001.

[35] Hornborg, A. *Global ecology and unequal exchange : fetishism in a zero-sum world.* Routledge, New York, NY, 2011.

[36] Kondepudi, D., and Prigogine, I. *Modern thermodynamics: from heat engines to dissipative structures.* John Wiley & Sons Chichester, 1998.

[37] Lawn, P., and Clarke, M. The end of economic growth? a contracting threshold hypothesis. *Ecological Economics 69*, 11 (2010), 2213—2223.

[38] Lotka, A. J. *Elements of mathematical biology.* Dover Publications, 1956.

[39] Marx, K. *Capital, volume I.* Harmondsworth: Penguin/New Left Review, 1867.

[40] Max-Neef, M. Economic growth and quality of life: a threshold hypothesis. *Ecological Economics 15*, 2 (1995), 115—118.

[41] McNally, D. *Global slump: The economics and politics of crisis and resistance*. PM Press, Oakland, 2010.

[42] Meadows, D. *Thinking in Systems: A Primer*. Chelsea Green Publishing, Dec. 2008.

[43] Mirowski, P. *More heat than light: economics as social physics, physics as nature's economics*. Cambridge Univ Pr, 1991.

[44] Mones, E., Vicsek, L., and Vicsek, T. Hierarchy measure for complex networks. *PLoS ONE 7*, 3 (Mar. 2012), e33799.

[45] Morowitz, H., and Smith, E. Energy flow and the organization of life. *Complexity 13*, 1 (2007), 51—59.

[46] Mumford, L. *The myth of the machine [Vol. 2], The pentagon of power*. Harcourt, Brace & World, 1970.

[47] Nitzan, J. *Inflation as restructuring. A theoretical and empirical account of the US experience*. PhD thesis, McGill University, 1992.

[48] Nitzan, J., and Bichler, S. *Capital as power: a study of order and creorder*. Routledge, New York, 2009.

[49] Odum, H. T. Self-organization, transformity, and information. *Science 242* (1988), 1132–1139.

[50] OECD. Measuring productivity - OECD manual, 2001.

[51] Polanyi, K. *The great transformation*. Beacon Press, Boston, 1964.

[52] Robinson, J. The production function and the theory of capital. *The Review of Economic Studies 21*, 2 (1953), 81—106.

[53] Schmidt, J. *Disciplined minds: A critical look at salaried professionals and the soul-battering system that shapes their lives*. Rowman & Littlefield, 2001.

[54] Schrdinger, E. *What is life?: With mind and matter and autobiographical sketches*. Cambridge University Press, 1992.

[55] Smil, V. *Energy in world history*. Westview Press, Boulder, 1994.

[56] Smith, A. *An Inquiry into the Nature and Causes of the Wealth of Nations*. A. and C. Black. Originally published in 1828, Edinburgh, 1863.

[57] Solow, R. M. A contribution to the theory of economic growth. *The quarterly journal of economics 70*, 1 (1956), 65–94.

[58] Steindel, C. Chain-weighting: The new approach to measuring GDP. *Current Issues in Economics and Finance, Federal Reserve Bank of New York 1*, 9 (1995).

[59] Stern, D. The role of energy in economic growth. *Annals of the New York Academy of Sciences 1219*, 1 (2011), 26—51.

[60] Turchin, P. Warfare and the evolution of social complexity: a multilevel-selection approach. *Structure and Dynamics 4*, 3 (2010).

[61] Turchin, P., and Gavrilets, S. Evolution of complex hierarchical societies. *Social Evolution and History 8*, 2 (2009), 167—198.

[62] Veblen, T. *Absentee ownership: business enterprise in recent times: the case of America*. Transaction Pub, 1923.

[63] Victor, P. Questioning economic growth. *Nature 468*, 7322 (Nov. 2010), 370–371.

[64] Vitali, S., Glattfelder, J. B., and Battiston, S. The network of global corporate control. *PloS one 6*, 10 (2011), e25995.

[65] Warr, B., and Ayres, R. Useful work and information as drivers of economic growth. *Ecological Economics 73* (Jan. 2012), 93–102.

[66] Wilson, E. O. *Consilience: The unity of knowledge*, vol. 31. Random House LLC, 1999.

[67] Wolff, E. N. The asset price meltdown and the wealth of the middle class. Tech. rep., National Bureau of Economic Research, 2012.

[68] Wong, S. *Foundations of Paul Samuelson's Revealed Preference Theory*. Routledge, New York, 1978.