real-world economics review, issue no. 82
subscribe for free

The trouble with distribution theory

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Abstract
Despite two centuries of work, income distribution remains a problem in search of a credible theory. By credible, it should be understood, a theory that is scientifically sound – in short, consistent with the underlying laws of mechanics – and empirically verified. This paper examines the problem of income distribution from a number of perspectives, including historical, scientific and moralistic. It will be argued that, for a panoply of reasons, the profession set out to tackle the problem of income distribution without first of all having resolved satisfactorily the more basic problem of modeling production, making for the current situation in which distribution theory is little more than a logical construct, the underlying fundamentals of which sit in violation of the principles of basic physics (classical mechanics), generating increasingly questionable results. Various alternative theories (historical and current) are examined, as are the associated policy options. The upshot is that the fundamentals underlying distribution theory have to be updated, as does the policy agenda as advocated by writers such as Thomas Piketty and Joseph Stiglitz.

JEL codes O40, O47, O57, Q43

Key words distribution theory, scientific fundamentals, consilience

1. Introduction

Interest in the problem of income distribution has been, over the course of the past two centuries, anything but orderly, being more a series of responses to real-time crises. Take, for example, Friederich Engels and Karl Marx and the radicals whose mid-19th century interest in the question of income distribution was in large measure a response to the business cycle and what at the time appeared to be a form of secular stagnation. This led to the theory of surplus value, the cornerstone of Marxian economics, and ultimately, to the neoclassical rejoinder in the form of the Euler equation (i.e. neoclassical distribution theory).[1] Fast forward to the Financial Meltdown of 2008 when, once again, income distribution, specifically a highly skewed distribution in favor of the owners of capital, was invoked as one of the leading causes, prompting a renewed interest in the problem.[2]

In both cases, questions relating to equity and fairness, not to mention employment and overall macroeconomic considerations, pushed and continue to push the debate forward. Lacking, however, was and is a more scientific, time- and issue-invariant, approach to the question. The downside or fallout has been the emergence and the continuing emergence of poorly formulated alternatives, including the work of Thomas Piketty whose underlying fundamentals differ little from conventional approaches. For example, his *r-g* rule is based, in large measure on the outdated Harrod-Domar growth model which assumes Leontief fixed proportions technology. Further, the bulk of his argument regarding income inequality is based on the emergence of a set of "super managers" whose role in production is unspecified. Consequently, he stopped short of providing a theoretical justification for their

[1] According to Marx, surplus value is equal to the new value created by workers in excess of their own labor-cost, which is appropriated by the capitalist as profit when products are sold.
[2] This is sometimes referred to as the Rajan hypothesis (Rajan, 2010). See also van Treeck and Sturn, 2012.

disproportionately high share of income, something a complete account of income distribution and inequality should do.

This paper attempts to examine the problem of distribution from a historical, analytical, scientific and empirical perspective.[3] The upshot is relatively straightforward, namely that the problem of distribution got off on the wrong foot, having being usurped by a host of other problems and issues, including the business cycle, weak growth and rising unemployment. In this paper, we propose to analyze it from first principles – that is, the underlying physics of material processes and the basic principles of Western-style property law.

To this end, we frame the discussion in terms of three questions. The first is: is there a scientifically-consistent rationalization for the existing factor distribution of income, and if not why not? This then leads us to the second question, namely if physical productivity is the underlying basis for income distribution, then what would the corresponding distribution of income look like? The third and last question is: can the existing distribution be reconciled with a physical productivity-based distribution?

The paper is organized as follows. To begin with, we present a short history of distribution theory, which then segues into addressing our first question, namely is there a scientifically-consistent rationalization for the current distribution of income. Not finding one, we then turn to examine the properties of a pure physical productivity-based standard. As the latter has been and continues to be the revealed preferred standard in Western industrialized economies, we then examine possible rationalizations of the existing distribution. Among these is the energy rent-based rationalization (Beaudreau 1998,2005) where the owners of energy-based inputs and non-energy-based factor inputs (labor, capital, management) bargain over the resulting energy rents.[4]

Should income distribution be based on the notion of property – that is, of a factor's productivity? In other words, as in the case of neoclassical distribution theory, should factors be paid what amounts to their property – to which they have a claim – namely their marginal productivity? While to most, this will appear to be obvious, it bears reminding that according to classical mechanics, modern-day labor and capital (simple and complex tools) are not physically productive.[5] Only energy/force is physically productive, implying that given the supervisory nature of labor, neoclassical income distribution theory breaks down.

Theoretically speaking, if one were to invoke a pure productivity standard, complete with the associated property rights, then all of output (value added) would be attributed to the owners of energy. But this then raises a problem, namely incentive-compatibilizing the owners/providers of capital and labor. In other words, if all of the product reverts to the owners of energy, then what would be in it for the owners of what we shall refer to as the owners of the organizational inputs (labor and capital)?

[3] A search of EconLit revealed no comparable/similar work – that is, critiques or surveys of income distribution theory.
[4] For more on the bargaining approach to income distribution, see Pissarides 2000; Bental and Demougin 2006; 2008; Jones 2003.
[5] Consequently, the first and second derivatives of the corresponding twice-differentiable production function have no meaning, scientifically speaking. That is, beyond the properties of the derivatives.

2. Income distribution theory: a history of missed opportunities, improvisation, and failure

In this section, we examine the history of distribution theory, starting with its origins. In short, it is argued that its origins coincided with the appearance of non-family, non-clan, non-tribe-based specialization. Prior to this, artisans and others tradesmen produced wealth using simple material processes. As they were the owners of all of their factor inputs (energy, tools, supervision, management), the question of the apportionment of the output among individual inputs (i.e. tools, energy) did not arise. As it turned out, the first occurrence of the distribution problem coincided with the feudal period where landowners hired peasants to till their lands. Consequently, the owners of the land and labor – and tools – were not one in the same. The result was one of the first incentive-compatible contracts, namely that of the laborer, the terms of which were fixed, or firm, giving rise ultimately to the nouns, firm and farm.[6] It turned out that the distribution of the product had little to do with physical productivity and everything to do with subsistence and risk assessment. At the very least, farmers or tenants has to eke out a living, and at the very most, the better they were in negotiating, the greater was their share of the product.[7]

Enter the industrial revolution with its heightened specialization and the problem of distribution. As workers had to be paid prior to the product being sold and revenue earned, a conundrum arose, namely how to pay workers in the absence of a revenue flow? Early writers resorted to what was known as the wage-fund, or the monies the entrepreneur had put aside (essentially saving) with which to remunerate his workers (Quesnay 1758, Mill 1848). As this amount was fixed, so was the "wage-fund." As described, the wage-fund pre-dated a well-developed banking system with modern-day credit facilities (i.e. real bills).

In the early years of the industrial revolution, private, credit-issuing banks provided the wherewithal to finance production, lifting the constraint imposed by the wage-fund. Bills of exchange were issued and used to remunerate labor and the owners of all variable factor inputs. However, the problem of distribution remained whole and unaddressed. That is, until the early 19th century when stagnation appeared to set in. Perhaps the earliest writer to address the issue was industrialist. Robert Owen who attributed the downturn to "insufficient purchasing power" owing to low wages. In short, technological advances had outpaced wage growth, resulting in insufficient demand. This led to what would become Owenism, consisting of a form of local communism where money/credit would be replaced by "labor certificates" in an amount equivalent to potential output, and distributed according to need (Owen, 1827).

Continuing stagnation in the early 19th century resulted in other similar forays into social engineering, the most important – and notable – of which was Friederich Engels and Karl Marx's "Communist Manifesto," which unlike Owen, brought the distribution question to a head. Unlike Owen who had advocated a wholesale overhaul of distribution as well as the medium of exchange, Engel and Marx went to the crux of the issue by invoking property rights. Starting from the classical view according to which only labor is physically productive, they went on to argue that profits or payments to the owners of capital were unjustified, illegitimate, and hence a form of theft. After all, in a world in which physical productivity is the

[6] The noun firm is a variant of ferme, French for firm.
[7] From an energy point of view, the ultimate and only factor input is the solar radiation involved in photo-synthesis. The resulting output, it bears reminding, is used by the farmer as an input, providing him with the energy to "farm" – that is, till the land. In such a setting, the Physiocratic contention that only agriculture is productive holds.

basis on which to set wages or factor payments in general, then all of output should be paid out to the owners of labor – in short, the workers. So was born the classical-inspired labor theory of value, which cast a pall on the nascent field of political economy.

From a theoretical point of view, Engel and Marx were right. The classic theory of production, largely based on Chapter 1 of Smith's "Wealth of Nations," focused on labor productivity. Capital was, as such, not physically productive. How then to justify capital's non-negligible share in national income? In short, this task would fall upon the shoulders of William Stanley Jevons (1874) and Alfred Marshall (1890), both of whom essentially decreed that capital was physically productive, complete with a marginal and average productivity, thus bringing to a close the issue. The result was neoclassical production theory, where both labor and capital are viewed as physically productive. Invoking Euler's Theorem resulted in modern-day distribution theory according to which the marginal products of each factor multiplied by their respective quantities exhausts total output. This approach to distribution was corroborated in 1928 when Charles Cobb and Paul Douglas provided the first numerical estimates of the neoclassical production function (specifically, output elasticities), elevating it to the status of economic law – or so it was thought.[8]

The irony in Douglas' work was the fact that according to him, factor markets in the 1920s had failed workers. Specifically, productivity had increased throughout this period without a concomitant increase in wages. The thrust of his work with mathematician Charles Cobb was to plead in favor of higher wages, based on what he considered to be a historical regularity. That is, overall productivity gains should be shared according to a 75-25 split.

While now firmly ensconced in mainstream production and distribution theory, the performance of the empirical Cobb-Douglas production function since has been less than stellar. In fact, most studies employing more up-to-date estimation techniques have been unable to replicate Cobb and Douglas's original results.

3. Neoclassical distribution theory: empirical irregularities

Neoclassical distribution theory is based on the existence of a well-behaved, continuous, twice differentiable production function defined over capital and labor. Starting with Wicksteed in 1894 and culminating with Charles Cobb and Paul Douglas' 1928 estimates of capital and labor's output elasticities, neoclassical distribution has rationalized the existing distribution of income in terms of productivity, and hence, in terms of basic property law (Cobb and Douglas 1928). That is, capital and labor are paid or receive the value of that which is theirs, that which is owed to them. It therefore follows that stable, time-invariant estimates of the respective output elasticities are essential for the theory to hold.

Unfortunately, time has not been kind to the Cobb-Douglas production function and to the Cobb and Douglas' initial estimates. Highly criticized by contemporaries as an approach to understanding production, subsequent estimates proved to be near-fatal. For example, Schlicter (1928) openly doubted whether factor shares remained constant over time, in addition to the underlying assumption that capital was always fully utilized over the business cycle. Williams (1945), Douglas (1948) and McCombie (1998) showed that the resulting

[8] After repeated tests involving data sets from different countries and industries, Paul Douglas came to speak in terms of "laws of production." See Douglas, 1948.

estimates were sensitive to the inclusion of certain data points. Recently, Fraser (2002) pointed to the presence of collinarity in Douglas' original and subsequent data (U.S., Massachusetts, Australia, New Zealand), and found that when corrected using a Generalized Maximum Entropy (GME) estimator, the results were significantly altered. Referring to Table 2, taken from Fraser (2002), we see that the output elasticities for capital, became negative.

Table 2 Fraser (2002)'s GME estimates of output elasticities

Table 6: Least Squares Estimation
Cobb-Douglas Functional Form With Technical Change

Parameters	USA	MASS	NSW	VIC	NZ
α	2.84*	1.983*	-0.15	-2.175	-2.0513**
	(1.362)	(0.29)	(0.5)	(1.536)	(1.13)
δ	0.048*	0.0267*	-0.0013	-0.0248	-0.013*
	(0.021)	(0.0028)	(0.0055)	(0.0176)	(0.005)
β1	0.913*	0.631*	0.697*	0.799*	0.403*
	(0.134)	(0.064)	(0.113)	(0.335)	(0.119)
β2	-0.54	-0.111*	0.343*	0.697**	0.904*
	(0.34)	(0.045)	(0.106)	(0.369)	(0.139)
R^2	0.9622	0.9882	0.993	0.9397	0.9262
F	195.929*	1001.848*	1188.83*	110.14*	84.649*
DW	1.6014	0.971	1.614	0.6529	1.467
F Test (β1+β2=1)	4.37*	50.52*	0.11	1.97	3.63**

Source: Fraser (2002).

On theoretical grounds, it implicitly assumes an elasticity of substitution between capital and labor of unity. Finding this to be overly restrictive, Arrow, Chenery, Minhas and Solow (1961) proposed a generalization in the form of the constant elasticity of substitution (CES) production function. Heretofore, the data would reveal the elasticity of substitution between what were two non-physically productive factor inputs. Other refinements of the Cobb-Douglas production function included the Translog, the Normalized Quadratic and other functional forms. The upshot was straightforward, namely that the original Euler equation failed to capture well, the underlying production relationships.

Recently, a number of writers have questioned the fundamentals underlying the Cobb-Douglas, or neoclassical approach to income distribution, focusing on the relationship between the estimated output elasticities and the actual underlying technology. Their argument is simply that the estimated output elasticities do not reflect the true technology, but rather are simply capturing factor shares (Beaudreau, 1995; Kummel et al., 2008; Miller 2008; Ayres et al., 2013)

4. A consilient model of production

The notion that factor payments should somehow be tied to productivity can be traced back to Engel and Marx and their allegation of theft directed at the owners of capital for illegally appropriating a share of the "value." As argued, this was based on the classical theory of production, which focused exclusively on labor. This led to the neoclassical response, in which it was decreed that capital was physically productive, in violation of classical mechanics (Beaudreau, 1998; 2016), According to classical mechanics, tools (simple and complex) are

not physically productive as they are not a source of energy.[9] Instead, they affect second-law efficiency, or the ability of energy to do work. The better the tool, the more work can result from a given quantity of energy/force.

Adding insult to injury, it turned out that not only was capital not physically productive, neither was labor. From the dawn of the industrial revolution, labor's role had gone from that of energy source to that of machine supervisor, or what Marshall himself referred to as "machine operative." Workers – now including women and children – oversaw the workings of machines, powered by steam.

We may now pass to the effects which machinery has in relieving that excessive muscular strain which a few generations ago was the common lot of more than half the working men even in such a country as England in other trades, machinery has lightened man's labours. The house carpenters, for instance, make things of the same kind as those used by our forefathers, with much less toil for themselves. Nothing could be more narrow or monotonous than the occupation of a weaver of plain stuffs in the old time. But now, one woman will manage four or more looms, each of which does many times as much work in the course of a day as the old hand loom did; and her work is much less monotonous and calls for much more judgment than his did (Marshall, 1890, p. 218).

If we are to begin to understand the problem of distribution and in the process avoid the cognitive dissonance found in the writings of Marx and Marshall, then it is imperative that we start from first principles, specifically from a model of material processes that is consistent with the laws of physics and thus unassailable, scientifically speaking. In this section, we present such a model, namely the energy-organization approach to modeling material processes which bridges mechanics, applied physics and economics.[10]

We begin by presenting the Energy-Organization (*E-O*) approach to modeling material processes (Beaudreau, 1998). Drawing from material process sciences (engineering, biology), it models wealth in terms of two universal factor inputs, namely broadly-defined energy and broadly- defined organization. Both are necessary conditions in all material processes whether it be in biology, chemistry, engineering or economics. The model is formalized in terms of Equation 1 where W_t, E_t, T_t, and $S(I_t)$ refer to wealth, energy, tools and supervision at time t, respectively.[11] Supervision, in turn, is assumed to be increasing in I_t. That is, more information leads to better and more effective supervision. η refers to second-law efficiency, which, as shown, is a function of T_t and $S(I_t)$.

$$W_t = \eta[T_t, S(I_t)]E_t \qquad (1)$$

[9] According to Betts (1989), "Machinery is used to change the magnitude, direction and point of application of required forces in order to make tasks easier. The output of useful work from any machine, however, can never exceed the total input of work and energy. (Betts, 1989, 172)." Arthur Beiser, in Modern Technical Physics, provided a similar definition: "A machine is a device which transmits force or torque to accomplish a definite purpose. (Beiser, 1983, 208)." See also Alting (1994).

[10] Stern and Kander (2010), Kander and Stern (2014) and Kander et al. (2014) presented a quasi-consilient model in which they considered a capital-labor Cobb-Douglas function, embedded within a nested Constant Elasticity of Substitution (CES) production function with energy inputs. This is similar to the E-O approach. However, it continues to assume that both labor and capital are physically productive, thus violating the laws of physics.

[11] These are used instead of capital and labor in keeping with the engineering and applied physics literature.

$\eta[T_t, S(I_t)]$ corresponds to the broadly-defined organization input, while E_t corresponds to the broadly-defined energy input. While E_t is sometimes referred to as energy consumption *per se*, technically it refers to available work or neg-entropy. As energy cannot be created nor destroyed, it follows that energy is not consumed *per se*, but rather overall entropy is increased. Second-law efficiency (i.e. η) is assumed to be increasing in tools and supervision. For the sake of discussion, it will be assumed that the latter are qualitative and not quantitative variables. That is, second-law efficiency is increasing in the quality of tools and the quality of supervision.[12] A good example of the latter is James Watt's external condenser that increased the steam engines's efficiency (i.e. η) by 100 percent.

$S(I_t)$, supervision at time t, is assumed to be information-based, consisting of collecting, storing, and retrieving process-related information, and using it as part of an operating protocol/algorithm. This can be carried out/performed by what 19th-century British economist Alfred Marshall referred to as "machine operatives," that is, workers, or by computer-based automated control systems.

The model is sufficiently general to allow for energy and information deepening, which by definition consists of an increase in the energy/tool and information/ tool ratios, respectively. Historically, energy deepening has been associated with machine speed-ups where by applying more energy (steam, kwhs), tools produce more output per unit of time, while information deepening has been associated with more and better process and sub-process based information (Beaudreau, 2017).

4.1 Is Neoclassical distribution theory consistent wtih the physics of material processes?

As neoclassical distribution theory was/is founded on neoclassical production theory, which itself was based on Adam Smith's ill-fated, unscientific attempt at analyzing the role of the steam engine on labor productivity, confounded by a off-the-cuff response on the part of William Stanley Jevons and Alfred Marshall to Engel and Marx's allegations over the legitimacy of profits in the former (Adam Smith's world), the question of whether neoclassical distribution theory is consistent with the physics of material processes arises. In its basic version (two factors), it maintains that both capital and labor are physically productive. In its extended version (KLEMS), it maintains that capital, labor, energy, material and services are each physically productive, and substitutable (Berndt and Wood, 1975).

The idea that all factors are physically productive is firmly embedded in the neoclassical approach to production and distribution as well as the question of income distribution in general.[13] A good example is the current debate over IT (Jorgenson and Stiroh, 2000) where it is assumed – without any doubt or debate – that like all other factors, information is physically productive, complete with an estimable output elasticity. For example, William Lehr and Frank Lichtenberg, using government data, estimated a computer output elasticity of 0.06 (Lehr and Lichtenberg, 1999).

Unfortunately, such a view, while convenient, cannot be justified on scientific grounds – by which it should be understood on the basis of classical mechanics and applied physics. As

[12] At the aggregate level, both T and $S(I)$ are quantitative variables. That is, aggregate output is increasing in aggregate, economy-wide tools and equipment, and supervision.
[13] Over time, it has become common practice to literally throw any and all possible factor inputs into the production function. Interesting examples include the inclusion of highways as a factor of production.

shown in the previous section, according to the latter, energy and energy alone is physically productive, all other inputs being organizational in nature.[14] As labor has not been a source of energy/force since the Paleolithic era (i.e. that is, in general), it stands to reason that neoclassical distribution theory is not, nor will never be consistent with the physics of material processes. Table 2 presents a list of what are violations of the principles of basic physics and mechanics found in current neoclassical production theory. In short, all non-energy inputs are not physically productive, but are essential to the organization of material processes. In a sense, they are organizationally productive.

Table 1 Neoclassical production theory violations of basic physics/mechanics

Factor Input	Violation
Labor	Labor is essentially a supervisory input, overseeing machines.
Capital	Consists of simple and complex tools, provides mechanical advantage, is not however productive.
Managers	Organize material processes, higher form of supervision. Not physically productive.
Information	Not a source of energy. An input in the overall supervisory technology.
Robots	Set of tools that replace operator held power tools. Not a source of energy, hence not physically productive.

4.2 What would a physical productivity standard look like?

These findings lead us to the obvious question, namely what would a physical productivity-based income distribution standard look like? The answer to this question is self-evident. Like Engel and Marx who had identified labor as the only factor input and hence the only legitimate claimant to output, in this case, energy is the only physically-productive input, and as such, would be the only legitimate claimant to output.

All other factors, being organizational inputs, would not be entitled to a share of the output. Clearly, this would raise an important incentive problem. If all other inputs were excluded from the plunder, then they would have no interest in participating. This leads us to an important conclusion, namely that a pure productivity standard is inconsistent wtih production as we know it.

4.3 How can the existing functional distribution of income be understood?

As it currently stands, the owners of energy appropriate roughly between four and eight percent of output, while labor and capital appropriate the rest. Contrast this with a pure physical productivity standard where the reverse would be the case. One way of seeing the former is in terms of bargaining, specifically that the owners of labor and capital have, over

[14] Interestingly, the related fields of industrial relations and industrial psychology also assume, for the most part, that labor is physically productive, and hence wages should reflect the value of what is, in essence, the property of labor – his/her work. The field of industrial relations appears to be of two minds in so far as the role of labor and wages are concerned. There is the Cornell ILR stream which is decidedly neoclassical in its approach, and the other, more conventional stream which focuses on collective bargaining, almost at the expense of markets.

the course of the past two centuries, appropriated something we refer to as energy rents, which are by definition equal to the difference between the value of energy's physical productivity and the cost/price of energy.[15] We could refer to this as the energy rent pie, which is divvied up between the owners of the organizational inputs. For example, the owners of labor appropriate 50-60 percent, and the owners of capital, 30 percent and managers, the rest.

In other words, the current distribution can be understood as resulting from bargaining on the part of non-energy-based factor inputs. This is not unlike John K. Galbraith's view of income distribution in the 20th century as resulting from a form of bargaining between large corporations and large unions, the latter being referred to as "countervailing power" to the rise of large, vertically-integrated conglomerates. It is also consistent with Robert Owen's view of the role of the commune in income distribution, as well as with the Technocrats view of the role of the Technate in income distribution.

In Beaudreau (1998; 2005) I argued that income distribution in a world in which energy and organization are complementary inputs is best studied using cooperative bargaining theory. Accordingly, the owners of energy and organization bargain over their respective share of the product (i.e. payoff set). Theoretically, the distribution of income is the solution to this game. Since broadly-defined organization is a *sine quo non* of production, it is clear that energy's overall share of the product cannot be total (i.e. equal to one). Put differently, a pure energy standard is ruled out by the presence of organization. The difference will be appropriated by the owners of organization (i.e. the designers of and owners of the production processes, and the owners of the supervisory input).

4.4 Bargaining without outside options

I begin by defining the bargaining problem. The owners of energy and organization (e.g. the owners of energy (E), tools (T), the supervisory inputs (S), and lastly, the designers/owners of the production processes themselves (D)) bargain over

$$W(t) = \min\left[\frac{E(t)}{\beta_1}, \frac{T(t)}{\beta_2}, \frac{S(t)}{\beta_3}, \frac{D(t)}{\beta_4}\right]$$

The output, in this case, manufacturing value added.[16] Define S_E, S_T, S_S and S_D, where $[0 \leq \alpha_i \leq 1,\ \ i = E,T,S,D^{S_{i=1}}]$,

as the energy, tools, supervisor and designer/owner factor income shares, respectively. Also, assume that α_i where $i = E,T,S$ and D, defines factor i's bargaining power

$$[0 \leq \alpha_i \leq 1,\ \ i = E,T,S,D^{\alpha_{i=1}}]$$

Lastly, assume that factor i's utility is an increasing linear function of income. More specifically, $U_i = U_i[S_i W(t)] \forall i = E,T,S,D$.

[15] For more on the bargaining approach see, Pissarides, 2000; Duffy and Papageorgiou, 2000; Bentolila and St. Paul, 2003; Blanchard, 2006; Guscina, 2006; and Bental and DeMougin, 2005. Our approach differs in so far as the underlyuing fundamentals are concerned. This literature typically assumes that labor and capital are physically productive thus violating the laws of physics.
[16] Here, upper-level and lower-level supervisors are aggregated into one category, S.

This provides a general framework in which to study income distribution. In the absence of outside options, the simple bargaining problem is given by Equation 2, where the S_i's are chosen to maximize the product of utilities.

$$\max_{S_i} S = \frac{\text{TT}}{i = E,T,S,D} [S_i W(t)]^{\alpha^i} \tag{2}$$

Assuming that $\alpha_i = \frac{1}{4}$, then it is clear that the solution to this problem is given by $S_i^* = \frac{1}{4}$ for all $i = E,T,S,D$.

Thus, in a world devoid of outside options and in which preferences are identical, income distribution will be largely determined by bargaining power. That is, if the economic value of energy, tools, supervisors and production processes is nil, then their share of the overall income (output) pie will be determined by each factor's bargaining power. For example, the greater is lower-level supervisors' bargaining power, the greater is its share of the pie, so to speak.

4.5 Bargaining with outside options

The presence of outside options alters considerably the bargaining problem. For example, sup- pose that the owners of electric power can sell each kilowatt hour at a price of 7 cents. It stands to reason that, at the very least, the owners' share of manufacturing output must be equal to or greater then the corresponding market value of the power. Define ξ_i such that $\xi_i > 0$ to be factor i's outside option. The bargaining problem becomes:

$$\max_{S_i} S = \frac{\text{TT}}{i = E,T,S,D} [S_i W(t) - \xi_i]_{\alpha_i} \tag{3}$$

subject to:

$$S_i W(t) - \xi_i \geq 0 \forall i = E,T,S \text{ and } D \tag{4}$$

In this case, a bargain will be struck if and only if, at the very least, the various factor inputs receive their outside options; otherwise, negotiations will break down, in which case production will not occur. It therefore follows that Equation 4 must hold for all $i = E,T,S,$ and D.

4.6 The determinants of outside options and bargaining power

Among the determinants of the resulting bargaining solution are (*i*) each factor's outside option, and (*ii*) each factor's bargaining power. This leads us to examine the determinants of outside options and bargaining power. For outside options to have any meaning, there must exist alternative uses for energy, tools, and upper and lower-level supervisors. For example, the owners of electric power could consume their kilowatt hours instead of devoting them to generating value added. The owners of tools (capital) could opt for consumption over investment. Lastly, the owners of upper and lower-level supervisory skills could devote their time to leisure activities. In a world in which the number of firms exceeds one, the owners of these factor inputs could, theoretically, bargain with another firm. The point of the matter is that outside options are conditioned by each factor's set of alternative activities.

For all bargaining problems with more than one solution (i.e. the perfectly competitive bargaining solution, defined by a strict equality for Equation 2.6), bargaining power plays a crucial role in income distribution. For example, the more bargaining power the owners of supervisory inputs have over the owners of electric power, the greater will their share of the product be.

This raises the question of bargaining power *per se.* What determines bargaining power within the firm (i.e. among the owners of energy, tools, the supervisory input and the conceivers of production processes)? Unfortunately, while formal bargaining models provide much insight into the process of income distribution in the presence of rents, it provides little in the way of an exact bargaining solution.

Throughout 19th and 20th centuries, increasing energy use and the resulting energy rents led to calls on the behalf of labor to share in loot, so to speak. While machine operatives were not in any way responsible for the increase in output, they, their representatives, and/or members of governments nonetheless manifested a desire to share in them, one based on a number of criteria, from morality/justice to demand-related issues (i.e. increasing aggregate purchasing power). Table 3 presents a list of what are bargaining-related approaches to the sharing of what were/are energy rents, ranging from the Technocrats' and a guaranteed energy-based income (paid out in energy certificates), to John Kenneth Galbraith's notion of "countervailing power" in regard to the rise of the large multinational corporation, largely responsible for the rise in energy rents in the 1910-1940 era.

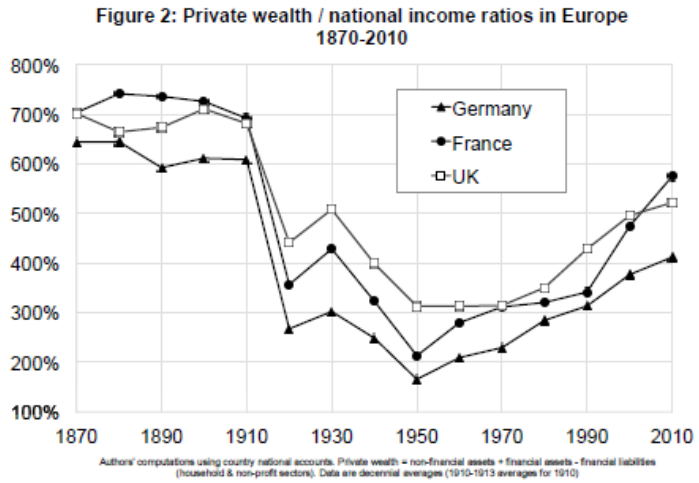
Table 2 Related bargaining-based approaches to factor shares

Source	**Process**
Labor Robert Owen (1827)	Labor Certificates
Technocrats (1933)	Universally-Distributed Energy Certificates
Congressman Huey Lewis (1934)	"Share the Wealth Movement"
John Kenneth Galbraith (1967)	Countervailing Power in Wage Negotiation
Post-WWII Tripartite collective bargaining in Europe	"Strict Bargaining Approach to Wages"
Pissarides (2000) Determination	Bargaining Approach to Wage
Beaureau (1998, 2005)	Energy Rent-Based Approach to Factor Shares.

5. Revisiting Piketty's stylized facts

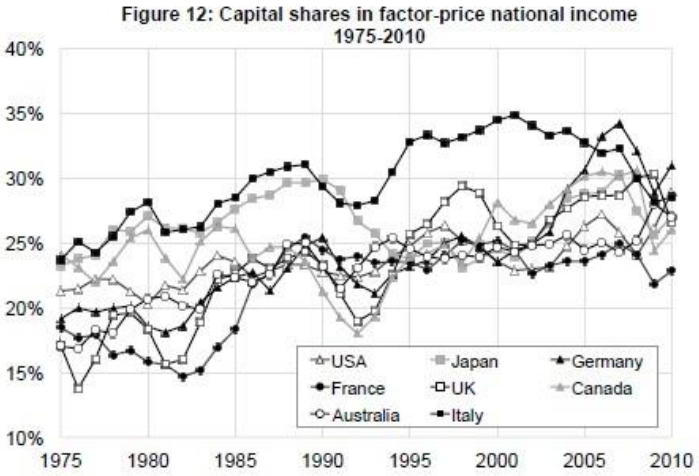
In this section, we revisit Thomas Piketty's stylized facts in light of what is a consilient model of material processes. Figure 1 presents his Stylized Fact No. 1, namely a diminishing capital-output ratio in the early part of the 20th century, relatively flat in the 1960s-1980s, only to increase in the 1990s, 2000s, and 2010s. He rationalized this in terms of (i) the destruction of capital in the two world wars, and (ii) the increase in the rate of capital accumulation since. The former effect is based on faulty reasoning as it supposes that capital is a passive input, having no bearing whatsoever on the level of output. Clearly, this was not and is not the case. If capital was destroyed in the two World wars, then would it not affect the West's ability to produce output (i.e. the denominator)?

Figure 1 Capital/income ratios



Rather, the U-shaped capital-output ratio should be seen as the result of two technological trends, namely energy deepening in the first half of the century, and massive ICT investment since 1980. By energy deepening, it should be understood a rising energy-capital ratio, specifi- cally a rising electric power-capital ratio. As pointed out in Beaudreau (2017), this corresponded to increasing machine speeds, increasing productivity per unit of capital and increasing output per unit capital. This came to an end in the 1970s, resulting in a flattening of the capital-output ratio. The second trend was the introduction of ICT technology – in short, information-based automation and control devices. Control technologies replaced and continue to replace workers. Another way of seeing this is that physical capital replaced and continues to replace human capital.

Figure 2 Capital's share 1975-2010



The second Piketty stylized fact is the increase in capital's share of overall income. As we pointed out, capital *per se* is not physically productive, making for a situation in which its income share is largely determined by its bargaining power over energy rents. Automation and the introduction of computer-based control devices have reduced the owners of labor's

bargaining power, resulting in a lower share of energy rents being appropriated by labor, and a higher proportion being appropriated by the owners of capital, as well as by those that were and are responsible for the introduction of these labor-saving technologies, namely what Piketty refers to as super-managers.

This leads us to the third Piketty stylized fact, namely the marked increase in the top decile's share of national income, attributed principally to the emergence of "super-managers" that command salaries in the millions of dollars. He attributed this to social norms, where those who set their own salaries are increasing generous towards themselves. This has prompted a debate within the profession, with some like Joseph Stiglitz pointing to a disconnect, specifically that there is clearly a disconnect between what executives are doing and how they are getting rewarded. We maintain that this phenomenon can easily be understood in terms of super-managers' share of energy rents, specifically that by introducing control technologies and implementing off-shoring strategies, they have, over the course of the past three decades, redirected the energy rents henceforth appropriated to labor and transferred them to both themselves and the owners of capital – in short, they have shared the plunder in terms of energy rents from automation and off-shoring (Epstein, 1996; Rodrik, 1997; Guscina, 2006).[17]

According to Frederich Engel and Karl Marx, the owners of capital in the 19th century had appropriated – without any basis in classical production theory – 30 percent of surplus value, or value in general, thus depriving the owners of labor of their rightful property. In this paper, we are making a similar argument – a sort of 21st century Das Kapital. Specifically, the owners of capital are appropriating a larger share of output and wealth, but not at the expense of labor, but rather at the expense of owners of energy, the only physically-productive input. The owners of labor have, as a result, been the big losers. However, as their share of wealth was itself largely illegitimate (the result of bargaining over energy rents), it stands to reason that the increase in capital's share has been achieved and is being achieved at the expense of the owners of energy.

Piketty's analysis has led him to a number of policy recommendations or measures, based largely on new forms of taxation aimed at reducing inequalities. For example, he called for a "confiscatory" global tax on inherited wealth, and a 80% tax on incomes above $500,000 a year. Both of these measures take aim at the trends documented above, regarding wealth and income. In other words, he recognizes both the legitimacy of both greater wealth as well as greater factor shares to non-labor income, and the legitimacy of the state to redistribute income. This, however, is where our analysis and policy implications differ. While not addressing the question directly, he implicitly assumes that factor payments made to capital and super-managers are based on a productivity standard, and thus are justified/legitimate. We, on the other hand, view factor payments as having no basis whatsoever in productivity, but rather are based largely on factor inputs' bargaining power over energy rents. For example, since the 1980s, the owners of capital along with super-managers have increased their bargaining power, and hence, increased their share over these same rents. This raises a number of policy questions regarding income distribution when Piketty's stylized facts are examined within the context of a consilient model of material processes.

[17] Bental and Demougin (2015) tell a similar story. Specifically, ICT innovation led to reduced moral hazard,lower worker bargaining power and lower wages.

6. Policy implications

Despite its progressive nature, Piketty's "Capital in the 21st Century" perpetuates the centuries- old notion that tools are productive and thus have a legitimate claim to output. It also conveys the notion that salaries paid to super-managers are legitimate and somehow reflect their productivity – that is, their physical contribution to wealth. In this section, we examine the policy implications of our consilent approach to modeling wealth creation within the moralistic context adopted by Piketty and others (e.g. Joseph Stiglitz), namely of "desired" greater equality. To this end, we consider three fundamental questions, namely (*i*) who can legitimately lay claim to energy rents? (*ii*) how should energy be priced? and (*iii*) how should a moral society – one that values equality – ensure an equitable distribution of energy rents?

The first of these questions, namely who can legitimately lay claim to energy rents?, is by far the most critical and fundamental question regarding income distribution as energy rents are the de facto basis of wealth. We maintain that it is implicit in the writings of the French Physiocrats, Robert Owen, Karl Marx, William Stanley Jevons in his 1865 "The Coal Question," the Technocrats, Frederick Soddy and numerous others. The Physiocrats maintained that agriculture was the source of all wealth. As agriculture is based on photosynthesis which, in turn, is powered by solar radiation, it stands to reason that according to them, all wealth is ultimately based on solar radiation/energy raising the question "who owns the sun?" In 1865, William Stanley Jevons, in the Coal Question, referred to coal as the source of all wealth, thus attributing, like the Physiocrats, to energy its rightful role/place in the creation of wealth.

Turning to the question of who owns energy and hence, the resulting energy rents, we are confronted with a series of questions, ranging from who owns the sun, the coal deposits, the oil wells, nuclear materials, etc.? For example, who owned the abundant coal fields of 19th century Great Britain? Who owns the fissionable materials that today power the growing number of nuclear power reactors in China and elsewhere? Is it the individuals who hold the title to the land and sub-soil in which these resources are located, or the corresponding nation states – that is, the owners of the sub-soil?

Second is the question of energy pricing. Theoretically, if it is priced at its marginal revenue product (i.e. price times marginal product), then in the event that the latter is greater than its cost, the owners of energy appropriate all of the rents. If, on the other hand, it is priced at its marginal cost, then it stands to reason that substantial energy rents will accrue to its users. This, we maintain, has been the case over the past two centuries and is currently the case, as substantial energy rents accrue to non-energy-related inputs.[18]

Turning to the third question, namely of an equitable distribution, the obvious answer is a straight division of energy rents by the population. That is, citizenship entitles individuals to an equitable share of the energy rents, defined over the relevant geopolitical space. Operationally, this would entail distributing claims to energy rents (i.e. Owen's Labor certificates, Technocrats' energy certificates) by fiat. The important point here is the understanding that such rents are scientifically legitimate and do not represent a form of transfer from the owners of capital. Clearly, for incentive-compatibility, the owners of capital

[18] This is sometimes framed in terms of the energy return on investment (EROI). According to Hall and Day (2009) and Hall et al (2009), the EROI for fossil fuels has been and continues to be positive, despite declining over time. In other words, energy rents continue to be positive.

would need to be compensated for having foregone consumption. This would entail that a fraction of energy rents would need to be set aside and paid to these individuals.

6.1 The problem with Piketty's wealth/income tax

In his work, Thomas Piketty advocated a universal tax on wealth, the idea being that the consequences of the growing concentration of wealth can only be reversed by way of a tax – and by the provision of public goods/redistribution. Among the reasons why we see this as problematic are the political and social consequences. That is, taxing the "1%" will invariably be seen as an infringement on the institution of private property and hence is seen as an attack on one of the most time-honored traditions in Western society.[19] That is, will be perceived of as one class (group of individuals) illegitimately appropriating the avails of another in a zero-sum game context.[20] Ironically, seen from an energy rent perspective, a Piketty-like tax is, in actual fact, a situation in which the state, the legitimate owner of energy and claimant to the associated energy rents, is simply reappropriating what is legitimately its own. Operationally, the state makes these rents available to users (firms) which in turn, share them with the owners of labor and capital, which ultimately are reappropriated via progressive income taxation. Recently, these rents are increasingly appropriated by the "1%" and being reappropriated by the state. Unfortunately, this is not the way in which such a tax has been/will be perceived given the current underlying fundamentals (i.e. that capital and management are physically productive).

Joseph Stiglitz's 2013 "market-power rents" approach can also be better understood from the point of view of energy rents. Specifically, he argued that the ratio of wages to productivity has been decreasing largely as the result of firms' increasing market power. Implicit in this view is the assumption that labor is physically productive. The problem, however, is that labor is not only not physically productive, but is increasingly redundant as an organizational input (i.e. supervising machines a la Marshall), thus diminishing its contribution to wealth. As its bargaining power has declined and continues to decline, its share of energy rents will also decline. This owes not to market power, but rather to bargaining power. As in the case of Piketty, advocating a corrective tax connotes the idea of theft, when in fact property rights have not been firmly established.

Karl Marx advocated a form of state ownership of capital of the means of production (i.e. capital), as they represented a form of theft – from the legitimate owners of all wealth, namely the workers. As we have argued, the legitimate owners from a pure productivity point of view are the owners of energy, which in most Western nations is the state. Marx's argument in favor of state ownership is analogous to our argument, but in what we would argue is a paleolithic context, where the motive power/energy input is provided by labor. That is, all motive force is provided by labor. However, even then, given that labor is ultimately powered by carbohydrates and proteins, a Physiocratic standard would be more appropriate, where the owners of the energy source (i.e. owners of land) would be the veritable owners.[21]

[19] New Deal-era pro-labor policies were perceived of by those on the right as an infringement on the rights of the owners of capital, and have since been disparaged in mainstream economics.
[20] This conflict has been endemic to industrial society from the getgo – that is, from the appearance of energy rents.
[21] In many ways, slavery illustrates the case of a pure productivity standard where the slave owner provides the food and reaps a rent, defined as the value of the work performed by the slave minus the cost of food. As such, the slave (body) is not physically productive, but rather an energy conversion and transmission device.

6.2 Other considerations

As we have shown, throughout recent history, the problem of distribution has been invoked as a leading cause of a skewed distribution of income and its macroeconomic consequences. Specifically, the growing concentration of income in the hands of the owners of capital was invoked by Karl Marx and by the Roosevelt Administration as the main cause of the business cycle. Others such as the Technocrats advocated a pure energy standard where energy certificates would be issued commensurately with the total outstanding energy balance (total energy available in a given geopolitical agglomeration), distributed according to what was an egalitarian rule, thus avoiding under-income, under-consumption and under-expenditure.

The upshot here is that science should guide policy. As it currently stands, the science behind the current distribution of income is fundamentally flawed as it is based on a flawed, unscientific model of material processes in economics. Until the latter situation is rectified, policy will be second best – at best.

7. Summary and conclusions

From the beginning, the debate over income distribution and the laws that govern it was based on a number of objectives, including a desire on the part of political economists to understand the determinants of wages and profits set against the Western legal mindset of productivity and property law. In other words, the profession sought to develop a theory of income distribution that would be both scientific in nature and legal in its implications. When Frederich Engels and Karl Marx declared that profits were a form of theft as only labor was physically productive, it touched off a debate that was to result in neoclassical distribution theory – in short, contemporary distribution theory based on the notions of labor and capital marginal productivity.

As we showed, instead of setting off an in-depth debate over the role of all factors in what were then revolutionary industrial production processes (i.e. powered by the steam engine), it led to what was a unscientific/unscholarly response on the part of the classics (Marshall, Jevons etc.) of simply decreeing capital to be productive, in violation of basic mechanics. Surprisingly, this is where the debate ended, with the result that current distribution theory stands in violation of the every elementary principles of basic mechanics.

Growing inequality, especially between the owners of labor and capital, has recently rekindled interest in the question of income distribution. Leading the charge has been French economist Thomas Piketty whose magnum opus, “Capital in the 21st Century,” can be seen as a modern- day rejoinder to Karl Marx’s “Das Kapital,” published in 1867. Like Marx, Piketty was motivated by growing inequality. However, unlike Marx who focused the bulk of his criticism on the legitimacy of profits, Piketty focuses on the laws that govern distribution in what is a neoclassical world, one that recognizes labor and capital, and super-managers as physically productive.

In this paper, we have maintained that herein lies the trouble with distribution theory, namely its weak underlying fundamentals (i.e. neoclassical production theory) and its condonation of the existing distribution of income (and its associated laws of motion) as theoretically legitimate. Not only can profits nor salaries to super-managers not be justified on productivity

grounds, the bulk of workers' salaries and investors' profits cannot be justified on productivity grounds, thus obviating the need for a consilient theory of distribution.

While not claiming to be definitive, we proposed a bargaining theory of distribution based on a consilient model of production processes. Having shown that a pure productivity standard is not incentive compatible, we proposed a bargaining model with outside options. Accordingly, income distribution was modeled as a bargaining problem over energy rents involving the owners of labor (supervision), capital (tools) and management (super-managers).

The resulting bargaining solution, we maintained, is consistent with both the current functional distribution of income, as well as with various approaches to income distribution, including John Kenneth Galbraith's countervailing power approach, where the owners of capital and labor bargain over the "plunder."

The key contribution, however, goes beyond the science of distribution, to the resulting policy implications, specifically with regard to recent trends in income distribution – specifically, those identified by such writers as Thomas Piketty and Joseph Stiglitz. First and foremost is the notion that the current distribution of income cannot be legitimized in terms of productivity, but rather, in terms of bargaining power, viewed as a social construct. Automation and out-sourcing have diminished labor's bargaining power at the expense of the owners of capital and super-managers, resulting in a labor share that is free falling over time.

Whereas Piketty sees taxation as the only option, we see myriad possibilities, ranging from a radical overhaul of income distribution based on a scientific model of production and its corollaries, to taxation, to the Technocrats' notion of a social wage or income. It is our view that if nothing else, this widens the breadth of the debate over income distribution, all the while correcting some of the more egregious flaws of mainstream distribution theory.

On a final note, we would like to make a case for a rapprochement between the science of material processes, the underlying implications and consequences, and the theory of income distribution. For over two centuries, the question has been examined on what were and are false premises. Until the debate becomes decidedly scientific, rancor and division will not only reign, but will increase in intensity.

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SUGGESTED CITATION:
Bernard C. Beaudreau, "The trouble with distribution theory", *real-world economics review*, issue no. 82, 13 December 2017, pp. 76-93, http://www.paecon.net/PAEReview/issue82/Beaudreau82.pdf

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