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Physiconomics and a claim for transdisciplinarity in economics

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In this paper, a claim for transdisciplinary in economics is put forward, pleading for a change of paradigm in economics and the introduction of a new area of study, physiconomics. William Stanley Jevons is presented as a forerunner of this transdisciplinary view. He introduced an emphasis on the importance of the relationship between economics and other social sciences. However, the article is not a historical re-evaluation but an intellectual discussion encouraging the emancipation of economics from engineering in favour of physics, sociology, law and psychology.

Introduction

Samuelson (1948, 2005) considered that economics can be reduced to an exact science based on physics and mathematics, in special on the differential calculus that mechanical physics uses to analyse the movement of bodies and their equilibria. He tried to apply in economics a methodology taken from an allegedly "hard science", physics. In this line of thought, econophysics has emerged as a new field of research that explores the use of methods and theories originally introduced in physics to solve economic problems. It has specialized in the analysis of financial markets, considering that markets act as if they were a group of electrons or liquid molecules interacting with each other (Vindel and Trincado, 2010, Trincado and Vindel, 2013). Econophysics includes uncertainty by using new instruments of statistical physics and chaotic or nonlinear systems (Sâvoiu and Simân, 2013). The concept of entropy, typical of physics, has also passed to economics through Georgescu Roegen ideas. Georgescu-Roegen (1971) claimed that the economic world is not mechanical as usually considered in mathematical economics, but an entropic process that applies the Second Law of Thermodynamics, replacing lower entropy with higher entropy states ("waste") (Rosser, 2016).

Econophysics, then, considers individuals as a mere electron that breeds a whole physical world, tending to equilibria or disequilibria processes. In this sense, other scholars have provided economics with the idea of a whole of which individual action is a part. Elinor Ostrom introduced a term, the holon, that symbolizes this unity that represents the whole and the parts, a Gestalt that allows free movement by creating rules without the need for an authority (Ostrom, 1990). The notion of a holon arises from the observation that everything in nature is both a whole and a part. Every holon is bound to two contradictory tendencies: to express itself and to disappear into something greater. For analysing this collective action in contention, Ostrom builds a framework that tries to understand specific situations with respect to a (common) resource and its sustainability over time, which leads to different institutional arrangements (Ostrom, 2005). In this sense, sociology, law, and physics are intermingled with economics

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(Trincado and García, 2024). However, the whole and the parts need not be under tension, being the individual acknowledged in the whole (Trincado, 2022, 153).

Then, in this paper, a deeper synthesis of disciplines is defended leading to greater degrees of transdisciplinarity in economics. It is not interdisciplinarity, but, as proposed by Ambrosino et al. (2021), Cat (2017) and Davis (2022), a claim for unity of science and an opening of boundaries in research fields which allow for a healthy evolution of science. We propose the birth of a disciple that, as we shall allege, can take William Stanley Jevons as a forerunner, physiconomics. This line of research will apply methods initially introduced in economics to physical data to economically maximize them for the common purpose of sustainability.

Jevons initiates economics as logic

The British economist William Stanley Jevons (1835–1882) may be considered a forerunner of a new line of research that may be called physiconomics. In the nineteenth century, Jevons stressed the relationship of economic life with physics and other disciplines (Trincado and Vindel, 2023). Early in 1860s, Jevons embraced the suggestion by Jennings (1969 [1855]) to base the laws of political economy on human psychology. He wrote in his diary of February 1860 that he had come to a "true comprehension of Value regarding which I have lately very much blundered" (Jevons et al. 1972, 7:120, cited Maas in Jevons, 2013, introduction xix). In 1871, the year of the marginal revolution, Jevons (2013) declared that it is utility, not production costs – as classical economists thought -, the one who determines the evolution of economics. The value of commodities is based on pleasure and pain – the utility of the final unit consumed. Then, the exchange ratio of two goods (price relation) is the reciprocal of the ratio of the marginal utilities. However, the utility cannot be directly measured. It can only be indirectly observed in the consumers' reaction to price changes. People have individual preferences; yet the market shapes a common world where free exchange leads honest agents to find equilibrium. "A unit of pleasure or of pain is difficult even to conceive; but it is the amount of these feelings which is continually prompting us to buying and selling, borrowing and lending, labouring and resting, producing and consuming; and it is from the quantitative effects of the feelings that we must estimate the comparative amounts" (Jevons, 2013, 11). According to Jevons, science is governed by laws of thought which could, where quantities are involved, be expressed in a mathematical form (Collison Black, 1972). In a looping circle, with his claim that "the mind of an individual is the balance which makes its own comparisons and is the final judge of quantities of feeling" (Jevons, 2013, 12) Jevons makes economics go to logic, instead of subjective utilitarian pleasure. Price ratios need to be ascertained; but they assume the logic of utility "underneath" them, as looking at the layer of the ocean may conceive a rich natural life within. So, what Jevons wanted to stress was that those relations to be found in nature may only be described in a logical manner and that the mathematical character of the measurement of feeling and motives draws economics to logic (a century after, Wittgenstein (1953) made the same claim for philosophical enquiry).

For Jevons, utility is the ultimate basis for value, but at the end of the day, resources must be available for exchange. So, Jevons concludes that value is determined in a "catena": production cost modifies supply; then supply sets marginal utility: and marginal utility is the basis for value (Jevons, 2013, 165). Jevons Catena was criticized by Marshall, who considered that the quantity mutually determines the price of demand and supply, and the determination is not a series. "Someone else however with equal Justice might say that C determines B and B determines A" (Marshall, 1898, 567). The Jevons catena made Keynes criticize Jevons affirming that he "chiselled in stone where Marshall knits in wool" (Keynes, 1956, 144). For sure, Jevons, at first defending subjectivism, was coming back to objectivism and classical economics. This was not the final point that Jevons wanted to make, but the fact that production could not be left to itself, as ethical paradoxes could occur.

In 1865, he introduced in *The Coal Question* (1865) a well-known paradox on the link between new technology and environment that has been widely used in physics. Engineers claimed that their inventions were milestones of a broader historical progress. But Jevons went against their delusions of grandeur showing that, paradoxically, not only energy efficiency will not lead to a diminished consumption of fuel, but new modes of economy will produce a consumption increase (Jevons, 1866). The invention of the James Watt steam engine led to an increase, not a decrease, of British consumption of coal (Rosenberg, 1989).

For Jevons, technology, being left alone and disregarding physics and economics, could be the origin of vicious circles. For instance, resource efficiency may decrease in the short run the cost of production, but as marginal utility decreases with an increase in production, there will be a direct increase of the consumption of commodities and an indirect increase in the consumption of other goods or services with which they are exchanged. Innovation does not imply a lesser use of resources: producers will use the resource more liberally due to a lesser cost of production and consumers will consume it more due to a lesser price. Besides, when we come to a non-renewable resource, demand may grow exponentially, while there is limited supply. We may allege that Jevons underestimated the importance of coal substitutes for producing energy (Clark and Foster, 2001), but the Jevons paradox is now part a core element of environmental economics (York, 2006). Rosenberg (1989) shows that the rebound effect may offset any savings of resources caused by the more efficient technologies.

Jevons had natural attraction for the utilitarian Jeremy Bentham as he was professor at the University College of London. Jevons was a Unitarian and there had long existed a connection between Unitarianism in theology and Utilitarianism in philosophy. However, his approach was that of a pure scientist (Collison Black, 1972). Veblen (1899, 411) points out that Jevons introduced a new method to economics based on logics, transforming classical economics with Benthamism. In *The Theory of Political Economy*, Jevons relates economics to Statical Mechanics, being laws of exchange like *Laws of Equilibrium* in the movement of a lever.

Although Schumpeter (1954, 952) wrote that Jevons was essentially based on the same principles than Menger and Walras, there was a Jevonian revolution in England. Menger was a subjectivist, Walras wanted to illustrate the general equilibrium, thus precluding the importance of the specific relations of value of men to commodities, to subsume it all to the whole. On the contrary, Jevons talked about a novel utility calculus, which considered rationality as a religion, but made it useless. At the same time, he did not deny the importance of costs in a long-run account of exchange value (Schabas, 1989, 61). He took only into account the pecuniary side of life but was inclined to stress the harmony of interests.

Furthermore, Jevons stressed the importance of the reform of logical science. He followed Boole claiming that the symbolic language of algebra is not only framed on notions of number and quantity, but on the Logic of Relatives, stressing the importance of the substitution of similar notions (Jevons, 1869) and the analogy between logical and mathematical forms. As Aristotelians, such as Peirce and De Morgan, Jevons based his systems of logic upon inclusion and exclusion (dependent on geometrical reasoning), instead of upon equality. Then, as MacColl, he claimed substitution of the equational form for the implicational form (Jevons, 1881). He defended pure logic based on probability and induction which give concrete scientific illustrations, principles established by Whewell and scrutinised by John Stuart Mill (Jevons, 1864. 1870, 1874). Although Mill considered that geometry is a physical science that can only be known by induction, Jevons responded Mill: although straight lines do not exist, we can experiment in our minds upon straight lines, as if they existed (Jevons, 1878b, 171).

Rationality is then, according to Jevons, based on inductive inference in which a new instance of the phenomenon is assumed to be like, analogue, equivalent or equal to another previous phenomenon. The same, mathematics comes to a formula to proceed in a certain way - by the application of the process of deduction. Nonetheless, our knowledge of future events is only probable (Jevons, 1873a, 1873b). "The deductive science of Economics must be verified and rendered useful by the purely empirical science of Statistics" (Jevons, 2013, 22). After a conversation with Helmholtz on the introduction of non-Euclidean geometry, Jevons defended the independence of truth and perception in the domain of geometry (Richards, 1988, 88–89).

Jevons as a forerunner of physiconomics

More than trying to take the methodology of physics for economics, as econophysics will do, Jevons wanted to create a transdisciplinary science, making in some way physics take the methodology of his recent created science of economics. For instance, Jevons presented a theory of the business cycles based on "sunspots" (Gallegati and Mignacca, 1994). He found a singular correlation between the price of corn and the activity of sunspots. This may be considered a spurious link, which Jevons may have taken randomly. However, it is the recognition of Jevons that he renounces subjectivism and admits the limits of nature, acknowledging the existence of a common world. In *Investigations in Currency and Finance* (Jevons, 1878a) Jevons published three essays; in the first, "The Solar Period and the Price of Corn" (1875), he spans a cycle of eleven years for prices of the production of agriculture depending on the sunspot cycle (Jevons, 1909, 194–205). In "The Periodicity of Commercial Crisis and Its Physical Explanation" (1878a) with "Postscript" (1882), he claims that in arid and semiarid lands, in agrarian societies weather has an important link with business activity (Jevons, 1909, 206–220). The third essay "Commercial Crisis and Sunspots Part I" (1878a) and "Part II" (1879) gives policy recommendation to avoid or reduce the recession of the business cycles (Jevons, 1909, 221–234 and 235–243 [1878a, 1979]). The increase in the coal price will create a British competitive disadvantage (Jevons, 1866, 24) and lead to possible famines and misery (Marshall, 1878). Confidence and consumer spending are influenced then by a solar cycle. More recently, Cass and Shell (1983) show that this variable determines expectations in a random way, making them uncertain, albeit being rational (also Peart, 1991).

Jevons made several contributions to science periodicals, such as Sydney Magazine of Arts and Sciences, most of them on meteorology (Harro Maas in Jevons, 2013, introduction xiv). He said that the commercial crisis in England happened simultaneously with high prices in Delhi, or even before; and that the cause cannot go after the effect. Besides, Jevons published on different studies on the formation of clouds, and he contributed to the statistical almanac of Waugh as regards to the Australian weather. As Jevons says: "Dr. Hyde Clarke then proceeds to argue in a highly scientific spirit that events so regularly recurring cannot be attributed to accidental causes; there must, he thinks, be some physical groundwork, and he proposed to search this out by means of a science to be called Physical Economy." (Jevons, 1909, 221–224).

Herbert Stanley Jevons (1875–1955), the son of William Stanley, was a unique follower of the work of his father on sunspots, a uniqueness which shows the difficulty of transdisciplinarity to take root in science. He was breaded in a family acquainted with the drawbacks of innovation, as the father of William Stanley Jevons, Thomas Jevons, an iron merchant, invented the first floating iron ship and went bankrupt in 1847, leading to ever-present financial difficulties to the family (Harro Maas in Jevons, 2013, introduction xii). The fact is that the son of William Stanley tried to continue with circular implications in economics. Herbert Stanley was very interested in Ethiopia and India, where he taught as an economics professor. He published on *The British Coal Trade* in Jevons (1915), where he relates wages, labour unions and the production cost and price of coal, which worsened energy dependence. In 1909 he publishes an article in *The Contemporary Review* entitled "Changes at the Sun's Heat as the Cause of Fluctuations of the Activity of Trade and of Unemployment". He also defended his father's ideas in H.S. Jevons (1910, 1933).

This line of research influenced in special William Foxwell, assistant lecturer to W. S. Jevons in the Chair of Economics at the University College of London and who succeeded Jevons as chair in 1881 (Foxwell in Jevons, 1909, introduction, xlii). Some literature has continued with the difficult-to-demonstrate correlation stated by Jevons. "Summing up, we can say that from a statistical point of view, there appears to be a clear correlation between the major cycles of non-agricultural business activity in the United States and the solar cycle of 11+ years." (Garcia-Mata and Shaffner, 1934, 26).

Is this naturalization of economics based on classical economics?

The *Coal Question* raised the problem of the limits to growth. Jevons showed that prosperity can lead to overpopulation and has limits that are not as far away in time as we may think. This idea was quite known in economic science as is the basis for the concept of the stationary state which emerged in the Enlightenment period (Jonsson, 2013). Missemer (2017a) shows the evolution of this idea of the limits of growth, which was due to the meanness of agriculture and food dependence related to population growth. Malthus (1798) and David Ricardo (1815, 1821) had a quite pessimistic view of this condition, although for Ricardo technological progress can delay its coming. However, population and agriculture seemed to be renewable resources, and preventive checks could be applied. Non-renewable resources are only mentioned in Ricardo (1815, 46-7, 67), McCulloch (1830, 1835) and Senior (1965). However, these classical authors were optimistic about the future possibilities of energy, as in the period, there was abundance of the resource.

Schabas (1990) notes that Jevons really wanted to go on to a new classicism. Classical economics alleged that nature is the limit to growth, not the other way round. Actually, physics was taking its methodology from economics, as Darwin was based on Malthus (1798) idea of population in his book published in 1859 *On the origin of species by means of natural selection*, showing the risks we may face on survival of species, including the human species. In 1838 Darwin read the works of Malthus, who believed that the inevitable scarcity of food in the face of a growing population would lead to an endless battle for existence where some will survive, and many would not. These ideas inspired Darwin on the struggles for survival. Before having read Malthus, he thought that reproduction kept populations stable, but when he observed some variations when certain individuals were slightly better prepared to survive and reproduce, leading to new species, he came to the idea of natural selection.

In short, according to Jevons, technological progress led to a greater rate of depletion of the coal mines of England (Alcott, 2005, 2008), which implied an emancipation from the conclusions of engineers (Missemer, 2017a, 29, 42–44). Jevons said that it is not easy to assess the recoverable stock of a limited resource (as we have said, Herbert Stanley Jevons took this baton). As the Jevons paradox raised doubts on industrialization, these limits to growth were somehow left out of economics for many years, at least until Marshall (1923, 803) or Hotelling (1931), who considered that resources substitution could be a solution and that technological change could still be fostered. The debate started over with the publication of *The Limits to Growth* (Meadows and Club of Rome's Project on the Predicament of Mankind, 1972). However, orthodoxy maintained its optimistic view in the long run. They still believed in the beneficial results of the market. Forrester (1971), Maddox (1971) and Nordhaus (1973) argued that if a basic exhaustible resource is depleted, an increase in its market price will force entrepreneurs to search for cheaper substitutes. Depending on the extent of these substitution possibilities, optimal exhaustion of finite resources was formalized by Dasgupta and Heal (1974), stressing the importance of the properties of production functions at the "corners".

Modern view of the Jevons paradox

The Jevons paradox implies that technological change and improved efficiency increase the quantity demanded, while they boost real incomes leading to a higher demand for resources. Against all historical resistance, a re-examination of this paradoxical result has been made by modern economists with a recognition for Jevons (Berkhout et al. 2000, Herring, 1999). In microeconomics, the Jevons paradox is first the result of the substitution effect (Clark and Foster, 2001), which size depends on the commodity demand price elasticity (Chan and Gillingham, 2015). The greater the elasticity of demand (the more horizontal the demand curve is, which relates the price with the quantity demanded), the greater the rebound effect. If there is only fuel as an input, it is more possible that the Jevons paradox occurs; if there are substitutes, it is less likely to occur.

But the Jevons paradox may also be due to an income effect, as when the prices of energy decrease, disposable incomes increase. Different indirect rebound effects are in Sorell (2009). It must be stressed that there is not much evidence from developing countries of the rebound effect, where there seems to be a higher rebound effect. However, in mature markets, normally we do not find a large direct rebound effect. In the 1980s, debate tried to relate energy price and energy efficiency (Khazzoom, 1980). The cost of capital of energy services determines the variations in the prices of energy, making energy efficiency an endogenous variable (Vindel et al. 2021).

In macroeconomics, the Jevons paradox is studied as an overspending when there is growth due to resource efficiency. Technological change and the increase in productivity have been chief economic goals from the first scholars that aimed at relating technology and economic growth in the twentieth century (Harrod, 1936; Domar, 1946, Solow, 1956). So, economic strategies were based on a concept of optimal technological change (Uzawa, 1965) and optimal growth (Cass, 1965), advocating for national innovation and R&D (Acemoglu et al. 2006). Then, the difference between the optimal economic growth and the economic growth is calculated. Macroeconomic models try to simulate the consequences of energy efficiency on consumption behaviour (Musters, 1995).

According to Saunders (1992) neoclassical growth theory confirms the Jevons paradox, due to the direct rebound effect and the increasing economic growth and real incomes, what implies that energy use will increase for the whole economy. Saunders affirms that at the microeconomic level - for individual markets - the rebound effect on consumption of the energy efficiency is less than 100%. But considering the whole macroeconomic level, it tends to increase total energy use (Binswanger, 2001). However, we may think that improved fuel efficiency is still worthwhile as it leads to increased material quality of life (Ryan and Campbell, 2012).

Besides, it is not clear if the growth of output is a cause or consequence of the increased energy consumption. Possibly, there is positive synergistic feedback between both (Ayres and Warr, 2002, Sorrell, 2009). This circular process depends according to Ruzzenenti and Basosi (2007) on increasing time lags. In Ayres and Warr (2002), the consumption of resources is both cause and consequence of growth and in Cleveland and Ruth (1998), the economic growth is a consequence that offsets all efforts toward dematerialization. But in general, neoclassical and 'endogenous' growth theory does not take the expansion in energy inputs as a cause of economic growth, as they claim that energy is a small share in relative terms of the total costs and it may be due to a 'technical change' that affects many other variables (Barro and Sala-I-Martin, 1995, Jones, 2001).

To counteract the rebound effect, a good understanding of the costs of actions and consumer behaviour is proposed (Dorner, 2019). Cyclical subsidies and taxes on clean technologies are proposed—or countercyclical policies if they are based on a Schumpeterian approach. This may be considered conservation policies aiming at making more expensive the cost of energy (Freire-González and Puig-Ventosa, 2015). According to environmental economists, the efficiency of fuel does not necessarily imply lesser depletion rates of fossil fuels and policies. Liberal policies try to make corrections to keep competition in the market. Being the price of electricity determined in a marginalist market, when the price of emission rights increase, they will give windfall profits to lower-cost technologies (in particular, installations that are already amortized). So, a tax could correct the situation.

Ecological economists go further and defend taxes on energy (Westergård, 2018) arguing that recent economic growth has increased the availability of energy inputs of 'high quality' (Hall et al. 1986), which differ in their ability to make the work useful (reflected in the notion of 'exergy') and in productivity (the differences in price per kWh). Countries, where economic growth and CO_2 emissions move in different directions, are said to have decoupling; if there is synchrony in those movements emissions, a trade-off exists between energetic neutrality and growth is based on intensive energy sectors.

A shift of paradigm an application of physiconomics

In this divide between environmental and ecological economists there is, however, a clear shift in paradigm, which includes the commons as a reality and a contradiction in the capitalism modus operandi. For instance, Kenneth Boulding (1966) stressed an overall contradiction of the economic process (Missemer, 2017a). Georgescu-Roegen (1971) claimed that the economic process is not mechanical as mathematical economics tends to represent, but an entropic process (Martínez Alier and Roca, 2000), which has given rebirth of radical ecological economics and theories of degrowth (Cosme et al. 2017). However, as shown by Herman Daly (1973), a steady-state economy is neither a solution. As

Suprinyak (2022) comments, Georgescu Roegen emphasized that the growth of population exert pressure over natural resources, showing that the neoclassical production function misinterpreted the study of agricultural activities. This inevitably imposes some idleness over the production, prescribing a recommendation of a balanced economic development even if it implies reduced urban leisure and consumption (Missemer, 2013, 2017b). Then, the objective of economic growth proposed by most economists (Harrod, 1965, 77) is put in doubt. Solow (1974) was the first economic growth specialist to accept such limits to growth, proposing the "polluter pays" principle.

Finally, Georgescu-Roegen (1986) introduced another paradox: a technology to be viable must have those qualities that characterize a living organism (Mueller, 2001) and solar energy is not the solution of higher levels of entropy. First, because radiation reaching the soil is very weak, second because a disproportionate amount of matter is needed to take advantage of solar energy in any significant amount (the viability concept is reconsidered in Vindel and Trincado, 2021). However, once more, this viability depends on the fact that we economize the most solar radiation available. In this sense, economic concepts must be applied to physical data, broadening the area of physiconomics. This line of research has already started in the literature. As an example, in Vindel and Trincado (2021), the commonly used in economics method of exceedance probability (the probability that a certain energy value is exceeded in a period) is applied to the viability of algal wastewater treatment. Discontinuities in the production and/or nutrient removal processes are assessed. A Risk Factor Improvement Index provided by storage is defined and improvements of up to 31% for the productivity and up to 20% for the ammonium uptake rate is reached. Also, in Trincado et al (2021) the concept of the opportunity cost is introduced in physical data. A viability analysis is applied to two systems for the treatment of wastewater based on the probability of not achieving an energy consumption threshold at least one day. This analysis, once more, improves the results of the study. Finally, Trincado and Vindel (2023) show that physics has no single index available to quantify both the amount and the variability of the solar resource, something needed to assess the location of a solar plant. Seasonal radiation data and changes throughout the year compromise the feasibility of solar plant projects. However, an index widely used in economics as the Gini coefficient is used, stressing the question of inequality in different places, a spatial methodology opposed to the incremental efficiencies of the technology emphasized by physics. This new methodology gives clearly better results for high latitudes and has the advantage of making comparisons possible, as it spans from 0 to 1.

Conclusions

In this paper, a new area of expertise has been proposed, physiconomics. As against econophysics, which uses methods that emerged in physics in economic data, physiconomics applies methods of economics to physical data, and tries to contribute to a transdisciplinary science. It tries to master nature and make resources economical in the way that economics does, as a relationship of scarce means that have alternative uses. The contribution that economics can make to physics is open and potentially wide and we hope it will have a long life and many offsprings.

As we have seen, Jevons' arguments wanted to emancipate economic study from engineering while relating it to physical and psychological phenomena. Engineers consider the world as a machine that needs to be tuned up to produce more and more output. But the common world has not such a consequentialist objective, and this utilitarian view reduces every natural resource to a material objective and conceals the whole picture. According to Jevons, we must not put the stress on productivity or specific commodities produced, but on the relative value and on the flow of time itself. Jevons paradox stressed an overall problem with technology and economic rationality and behaviour. In 1960s the debate turned global, as the processes of production and consumption were understood in terms of energetic waste. Capitalism processes were thought as unsustainable as the need for inorganic materials increased, coming out from the subsoil to the atmosphere. With this, Jevons was beginning a line of deep transdisciplinary synthesis which put into question utilitarianism and made science face the sustainability of the human race.

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The author declares no competing interests.

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