Energy as a Factor of Production: Historical Roots in the American Institutionalist Context

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ENERGY AS A FACTOR OF PRODUCTION: HISTORICAL ROOTS IN THE AMERICAN INSTITUTIONALIST CONTEXT

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Abstract

The relationship between energy and economic output is today discussed through the decoupling issue. A pioneering historical attempt to measure this relationship can be found in contributions by F. G. Tryon et al. at the Brookings Institution in the 1920s-1930s, in the American institutionalist context. This episode has scarcely been noticed in the literature. On the basis of textual analysis, archival material and econometrics, the purpose of this article is to provide a historical account of this corpus (context, originality), to assess the relevance of its statistical results, and to highlight the salient issues of the time that could feed into contemporary research. In particular, the articulation between empirical observations (inter-index correlation), theoretical implications (considering energy as a factor of production) and energy policy (global strategy rather than sectoral measures) is an old question deserving attention.

Keywords: decoupling, energy intensity, Tryon, Brookings Institution, natural resources, institutionalism, history of economic thought

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1. Introduction

The relationship between energy and economic output is today discussed through the decoupling issue. Since the 1980s, the economic and biophysical literature has explored the energy-output linkage with contrasted results (Ayres, 2001; Cleveland et al., 1984; Fischer-Kowalski et al., 2011; Kemp-Benedict, 2017; Stern, 2011; Ward et al., 2016); a disconnection between energy consumption and economic production remains uncertain, in particular for the whole world economy.

In the history of economic thought, this issue is not a new one, nor does it date back to the 1970s oil crisis. Roots with explicit attempts of measurement of the interrelation between energy and output can be found in the 1920s and 1930s, when Tryon (1927) published "An Index of Consumption of Fuels and Water Power" in the *Journal of the American Statistical Association*. As far as we know, this was the first contribution directly and statistically addressing the issue, even if Tryon did not use the words coupling or decoupling – he referred to "parallelism of the fluctuations" (ibid. 278) and "close correspondence" (ibid. 280) –, and even if resource scarcity and climate change were not his concern – he focused on labor substitution by mechanical power (i.e. a social question), because of the development of energy intensive machinery.

Tryon (1892–1940) was a geologist, economist and statistician, working at the US Geological Survey then at the US Bureau of Mines.[1] In the 1920s and 1930s, he published articles, reports and books on various mineral resources (coal, petroleum, gas, metals, non-metal minerals) but also on population, social and industrial issues.[2] He was a member of the Coal Commission in 1922–1923 (Smith, 1923, 1924) and of US delegations in conferences all over the world (e.g. 1924 World Power Conference in London, 1929 World Engineering Congress in Tokyo). In addition to his position at the US Bureau of Mines, he was a member of the Institute of Economics of the Brookings Institution, which was a central place of American institutionalism in the interwar period (Rutherford, 2011). Early contacts with Robert S. Brookings started in 1922, but Tryon had too much work at the Coal Commission to get involved in new projects at that moment.[3] From the mid-1920s to the mid-1930s, he worked as a part-time fellow (and for defined periods as a member of staff)[4] at the Institute of Economics, conducting various studies.

Tryon's 1927 pioneering work has sometimes been noticed in the literature, mostly with short references or small quotes.[5] Berndt (1978) is the only one who made some comments on Tryon's research, on specific points. Above all, no one has so far noted that Tryon's work took place within a larger program, with other colleagues from the Brookings Institution – a program we

[1] Tryon defined himself as a "mineral economist" (Tryon and Berquist, 1932, 1). The US Geological Survey (USGS) was – and still is – a federal agency responsible for a whole range of mineral studies. In the 1920s and 1930s, it was under the auspices of the Secretary of the Interior. The US Bureau of Mines (USBM) was founded in 1910 as an emanation of the USGS. In 1925, the Secretary of Commerce took such supervision. Tryon, whose contributions for the USGS started ca 1920, moved to the USBM at this moment, and stayed there until his death in 1940.

[2] We identified almost 60 references between 1920 and 1938. A few of them were published in major economic and statistical journals, as the *American Economic Review* (Tryon, 1921), the *Review of Economics and Statistics* (Tryon, 1926) and the *Journal of the American Statistical Association* (Tryon, 1927; Young and Tryon, 1931).

[3] Letter from F. G. Tryon to R. S. Brookings (Sept. 9th, 1922), FGTP, administration file.

[4] The late-1920s Brookings reports mention Tryon as "formerly member of staff, US Bureau of Mines" (Brookings Institution, 1928, 14; Moulton, 1929, 41). Evidence indicates that his cooperation with the Institute of Economics effectively started in 1924 – he went to Europe from June to August 1924 with its support (Smith, 1924, 41–42) – and prolonged most likely up to 1934, when the correspondence stopped between Tryon and the Brookings staff.

[5] We found references to Tryon (1927) in Ayres (2001), Beaudreau (1998, 2016), Cleveland et al. (1984), Court (2016), Hall et al. (2001, 2008); Kümmel et al. (2010, 2015), Lindenberger and Kümmel (2002), Lindenberger et al. (2017), Panesar and Fluck (1993).

propose to call the Brookings energy program.[6] Although the 1927 paper was the cornerstone of this program, other contributions were based on the same research.[7] Examining Tryon's 1927 contribution therefore requires not considering it as an isolated work, arising out of nowhere and not discussed at the time. A historical account of the whole Brookings energy program is needed to understand the reasons why the energy-output subject became a focus of attention at that time (1920s–1930s), in this American institutionalist context.

Beyond this historical account, our objective is to review in details the way Tryon (and his colleagues) pioneered the study of the relationship between energy and economic output. In particular, as we show in the following sections, the assumptions, methods and conclusions stated by Tryon (1927) are not alien to today's research concerns. His desire to articulate empirical observations (inter-index correlation) with theoretical implications (considering energy as a factor of production) and energy policy (global strategy rather than sectoral measures) is of particular interest.

The article is organized as follows. Section 2 provides a historical account of the Brookings energy program, in the institutionalist context. Section 3 focuses on Tryon's 1927 article, to identify the research questions, methods and results of the contribution. Section 4 provides an econometric assessment of Tryon's basic calculations, in order to measure the relevance of his interpretations and to clarify his methodology. Some concluding remarks close the article.

2. The Brookings energy program in context

2.1. Mineral studies at the Institute of Economics

In the interwar period, the economics landscape in the United States was pluralistic, with the consolidation of a neoclassical trend in the lineage of John Bates Clark and Irving Fisher, and with the progress and strong influence of institutionalism, characterized in its early years by a call for empirical realism and for the reform of economic and social settings (Rutherford, 2011, 7–8). Among the various places were institutionalism developed, the Brookings Institution played a vital role in he 1920s-1930s, with important figures such as Walton H. Hamilton, Harold G. Moulton, Isador Lubin and Edwin G. Nourse.

The Brookings Institution was created at the end of 1927 as a merger of three organizations – the Institute for Government Research, the Institute of Economics and the Brookings Graduate School of Economics and Government – all founded by Robert S. Brookings in the 1910s and 1920s. The Institute of Economics, launched in 1922 thanks to the support of the Carnegie Corporation (Rutherford, 2011, 162), lost autonomy in 1927, but continued to have specific research programs and a separate staff. As a (part-time) member of the Institute of Economics, Tryon was able to hire some assistants (Berquist, Schoenfeld, Young); most of them also came from the US Bureau of Mines.[8]

In the second paragraph of his 1927 paper, Tryon explains that his analysis is part of a broader study conducted by the Institute of Economics (ibid. 271). A reference to this project can indeed be found in a report of the organization, dated 1929, written by the then President of the Brookings, Harold G. Moulton:

> "The following investigations should be completed during the course of the coming year: [...] 9. *The Power Revolution*. By F. G. Tryon – A comprehensive survey showing the development of our power resources in the modern world and revealing the economic significance of power in our industrial society." (Moulton, 1929, 17-19)

This quote confirms that the energy program was not limited to Tryon's 1927 paper, which was already published at the time. Apart from

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[6] The historiography of the Brookings Institution (e.g. Critchlow, 1985; Rutherford, 2011; Saunders, 1966) does not make any focus on this particular program.

[7] See Tryon and Eckel, 1932; Tryon and Rogers, 1930; Young, 1930; Young and Tryon, 1931.

[8] Letters from F. G. Tryon to H. G. Moulton (March 3rd, 1928) and from H. G. Moulton to F. G. Tryon (May 5th, 1929), FGTP, administration file; see also Moulton, 1929, 43.

scattered contributions (e.g. Tryon and Rogers, 1930; Young, 1930; Young and Tryon, 1931), the collective book *Mineral Economics*, edited by Tryon and Eckel (1932), was one of the main deliverables. This book was the result of a conference series, firstly planned for the year 1930,[9] but eventually held during the year 1931 (Moulton, 1932, vii–viii). In line with the institutionalist priorities of opening up the field of economics to other disciplines, it shows the importance of multidisciplinary endeavor in the work carried out: both Moulton in the preface (ibid. vii) and Tryon and Berquist in their introductory chapter explain that "mineral economics [requires] a fusing of the viewpoint of economics with that of geology and engineering" (ibid. 1), and that scholars involved in this "branch of economic science" (ibid. 1) do not need to be specialists in all fields, but they "must understand the literature, [...] know where to seek advice, and [...] have the collaboration of technical men" (ibid. 36). This certainly led to the will of the Institute of Economics to cooperate with other organizations such as the US Geological Survey and the US Bureau of Mines in Washington.[10]

According to Moulton (1932, viii), H. Foster Bain, an eminent American geologist at the time, suggested to investigate the subject of mineral economics – Bain is the author of the chapter on scrap metals in the collective book (Bain, 1932). But the existence of early discussions (from 1922 onwards) between Tryon, Brookings and Moulton on "the creation and distribution of heat and power" rather suggests that Bain's encouragement was only one cause among others for the development of the project.[11]

The Institute of Economics had conducted studies on ore and power resources before Tryon's work. Under the authority of the Institute, Lubin (1924) published a book on the mining wages system, Hamilton and Wright (1925) one on bituminous coal, Lubin and Everett (1927) another one on the British coal industry. As stressed by Rutherdord (2011, 48, 177–79), the coal sector was a decisive point of attention for institutionalists, who tried to highlight the discrepancies between neoclassical models and practical realities, especially on competition and power relationships.

Tryon's 1927 project considered all sources of energy, not just minerals. This was consistent with the new interests of the Institute of Economics, ongoing studies focusing on new resources, in particular waterpower (Moulton et al., 1929). For the Brookings, the energy program was both the continuation of ancient projects, and an innovative track to measure the impact of coal, oil, gas and waterpower on the American way of production.

By examining all the work carried out within the Brookings energy program (see below for Tryon's 1927 example), we can see that it had the ambition to be (i) empirically grounded, (ii) theoretically valuable, and (iii) policy relevant. This was in line with the broad institutionalist project (Rutherford, 2011), and with the self-attributed missions of the Brookings Institution, i.e. to treat "enduring problems of theoretical significance as well as [...] questions of more immediate public import" (Brookings Institution, 1928, 4).

Empirical foundations (i) relied on the collection of data and their statistical treatments. The theoretical objective (ii) was Tryon's particular concern, mentioned at the beginning of his 1927 paper and for which he is cited in the literature:

> "The industrial position of a nation may be gauged by its use of power. [...] A theory of production that will really explain how wealth is produced must analyze the contribution of this element of energy. These considerations

[9] Letter from F. G. Tryon to the Committee on Training (Jan. 21st, 1930), FGTP, administration file.

[10] Beyond Tryon's involvement in the Institute of Economics, and the hiring of temporary assistants from the USBM, traces of explicit research collaboration between the institutions can be found in the archives, which contain drafts of agreement (e.g. "Cooperative Agreement between the Department of Commerce [via the US Bureau of Mines] and the Brookings Institution", FGTP, administration file). One may also note the recruitment of students from the Brookings at the USBM, such as Oscar Kiessling (Rutherford, 2011, 177f).

[11] Letters from R. S. Brookings to F. G. Tryon (July 7th, 1922) and from F. G. Tryon to R. S. Brookings (Sept. 21st, 1922), FGTP, administration file.

> have prompted the Institute of Economics to undertake a reconnaissance in the field of power as a factor of production." (Tryon, 1927, 271)

And the policy relevance (iii) appeared both through specific reports designed for public policy (e.g. Tryon and Schoenfeld, 1933) and through the general message that an energy policy could only be national and global, and by no means sectoral, in order to take into account potential substitutions between power sources, possibly modifying the expected effects of policy measures, and in order to account for the interdependencies between regions with diverse natural endowments and energy needs (Tryon, 1924b, 172; Nourse et al., 1934).

2.2. The Brookings energy program in the history of economics

The Brookings energy program, including Tryon's project to investigate the relationship between energy and economic output, took place in a period of concerns in the American society regarding the management of natural resources. In the mid-1920s, the energy sector was a source of anxiety for industrial life, military security and political intrigues – see for instance the Teapot Dome scandal (Yergin, 1991). Economists and observers from various backgrounds (technocrats, engineers, conservationists, etc.) succinctly or extensively wrote on energy sources, but the participants in the Brookings energy program did it in a way that we consider was fairly unique at the time.

In the 1910s-1920s, economists involved in conservation issues were often institutionalists, starting with Ely (1918). The majority of them were developing sector-oriented inquiries: Pogue (1921a, 1921b) was a specialist of the oil industry, like Stocking (1925); after extensive essays on forestry (Ise, 1920), Ise (1926) became interested in petroleum issues, with a focus on regulation. Other economists, with a more neoclassical approach like Gray (1913, 1914) and Hotelling (1931), [12] made important contributions to exhaustible resource analysis, but with a visibly reduced interest in the empirical foundations of their models.[13]

In this environment, the originality of the Brookings scholars was to insist on the empirical relevance of their work while considering energy as a whole, as a unified concept. Unlike studies on specific energy sources, Tryon et al. sought to conduct research on energy in general, which was definitely pioneering at the time.[14]

Tryon was aware of the innovative feature of the project. He considered that too few experts worked on energy,[15] and claimed to bring an original perspective to the economic profession – "power deserves more attention than it has yet received from economists" (Tryon, 1927, 271).

Participants in the Brookings project had some contacts, often indirect, with economists outside the group. Pogue (1933) made comments on *Mineral Economics*, even if he did not participate in the conference series. There were also a few, albeit anecdotal, connecting points between Tryon and Hotelling, because of their common interest in statistics. Tryon's 1927 paper was published in the same issue as Hotelling (1927)'s "Differential Equations Subject to Error, and Population Estimates". The two men met at the 1924 Christmas meeting of the American Statistical Association in Chicago (King, 1925). Hotelling carefully read Tryon's contribution to the meeting (Tryon and Mann, 1926), published in a collective book edited by Dublin (1926), because he reviewed the book for the *Journal of the American Statistical Association* (Hotelling, 1926). Yet his review, mainly descriptive, does not show any particular opinion on Tryon's chapter, except that it is on "the supply of

[12] Lewis C. Gray studied agricultural economics at the University of Wisconsin, notably with Richard T. Ely (Rutherford, 2011, 191f). But he soon became more interested in neoclassical approaches (Crabbé, 1983).

[13] For details on the Conservation movement economic thought, see Crabbé, 1983; Ramos Gorostiza, 2003; Missemer, 2017, chap.2; Smith, 1982. For a study of Hotelling's interest in empirical and political issues, see Franco et al., 2019; Gaspard and Missemer, 2019; Ferreira da Cunha and Missemer, 2020.

[14] As stressed by Mitchell (2011, 180) and Massard-Guilbaud (2019), the broad category of 'energy' became a political point of attention only in the 1970s. Before that, the focus was on particular sources or sectors.

[15] Letter from F. G. Tryon to H. G. Moulton (Jan. 21st, 1930), FGTP, administration file.

energy" (ibid. 504) and that, more generally, "the relation of population to natural resources is [...] a central problem, and the [...] chapters, dealing with this subject, are therefore of considerable interest" (ibid. 503). Apart from this episode, Hotelling never mentioned Tryon, or other contributions from the Brookings energy program, in his own research on natural resources.[16] In turn, there is no mention either of Hotelling's works in the Brookings deliverables. The only common result formulated by Tryon and Hotelling concerned competition in mineral industries: if conservation is the target, monopoly is more appropriate to delay resource extraction (Hotelling, 1931, 151; Tryon and Schoenfeld, 1933, 90). This convergence constitutes rather an exception than the rule.

With respect to the state-of-the-art in the 1920s, the Brookings energy program was a singular experience, considering energy as a whole with empirical concerns. In the long history of economic thought, the project can however partly be related to previous experiences. In his book *The Coal Question* (1865, 2nd ed. 1866), W. Stanley Jevons had already addressed the role of energy (in this case coal) in economic development, in the same way as Tryon and his colleagues (Frey, 1932, 37; Tryon, 1924b, 171; Tryon, 1925, 26–27; Tryon, 1936b, 423; Tryon and Mann, 1926, 114).[17] He had also already insisted on the competitive effects of resource exhaustion (Jevons, 1866, chap. 13–16; Tryon, 1936c, 285; Rice et al., 1936). Actually, a reference to Jevons can even be found in Tryon and Rogers (1930, 361) when
4|3 they examine fuel efficiency and mention the backfire version of the rebound-effect, whose conception is attributed to Jevons:[18]

> "The ultimate effect of the advance in efficiency may be to increase the consumption of fuel. As Jevons (1865) pointed out, 'As a rule, new modes of economy will lead to an increase of consumption, according to a principle recognized in many parallel instances'." (Tryon and Rogers, 1930, 364f)

In a sense, the Brookings energy program constitutes a renewal of Jevons' original intuition, applied this time to the United States, sixty years after its application to Britain.[19] Some differences however do exist, in terms of scope – Jevons was interested in coal, Tryon et al. in all sources of energy –, and in terms of forecasts – Jevons was more pessimistic on technology and resources substitution than the Brookings scholars.

Our historical account of the Brookings energy program therefore provides several results. First, Tryon's 1927 contribution was part of a broad energy program at the Brookings Institution, in the institutionalist context. Second, Tryon et al. proposed an original project in the 1920s in comparison to the state-of-the-art, by
considering energy as a whole, and by 4
combining empirical, theoretical and policy-relevant ambitions. Third, the Brookings energy program can be related to Jevons's pioneering work on coal, because of a common diagnosis on the role of energy in economic dynamics, and because of a common concern for empirical issues.[20]

[16] This remark includes Hotelling's archival papers (HHP), consulted at Columbia University. It is noticeable that Hotelling was recruited at Columbia University in 1931, then an institutionalist place (Rutherford, 2011, 239).

[17] On Jevons, see Alcott, 2005; Madureira, 2012; Martinez-Alier, 1987; Missemer, 2012, 2015, 2017; Pottier, 2014; White, 1991. Other, more confidential, previous experiences could also be mentioned (e.g. Dupin, 1827; see also Albritton Jonsson, 2020).

[18] The backfire version of the rebound-effect is also known as Jevons' paradox (Alcott, 2005; Missemer, 2012; Sorrell, 2009). It was rediscovered and developed in the second part of the 20th century (Brookes, 1979; Khazzoom, 1980).

[19] W. S. Jevons is also cited by Tryon and Mann (1926, 126f, 129) and Tryon (1929, 18). A British continuation of W. S. Jevons' project can be found in his son's 1915 book entitled *The British Coal Trade* (see Missemer, 2015; Turnbull, 2017). Interestingly, H. S. Jevons is also quoted in one contribution linked to the Brookings energy program (Kiessling et al., 1931, 18f). With respect to Britain, from a geological point of view, Tryon and Schoenfeld (1926a, 1926b, 1926c, 1926d) were interested in the comparison with the US.

[20] One may note that Jevons (1871) had fewer empirical concerns in his *Theory of Political Economy*, one of the starting points of the neoclassical approach to which institutionalists will later oppose.

3. Tryon 1924: measuring the energy-output relationship

3.1. The construction of an index of energy

Frederick G. Tryon published "An Index of Consumption of Fuels and Water Power" in the *Journal of the American Statistical Association* in September 1927. In December 1926, a preliminary version had been presented at the Christmas meeting of the American Statistical Association (King, 1927).[21]

Tryon's paper includes two graphs and one table of data. The objective of the analysis is to examine "the contribution of this element of energy" to "wealth" and "production" (Tryon, 1927, 271). This inquiry requires the comparison of several series of data, including information on energy consumption and economic activity:

> "One of the first problems uncovered has been the need of a long-time index of power, comparable with the indices of employment, of the volume of production and trade, and of monetary phenomena, that will trace the growth of the factor of power in our national development." (Tryon, 1927, 271)

In the 1920s, national accounting was not yet developed. To get an accurate view of the major economic variables, indicators still had to be constructed. Indexes were one type of indicators much discussed by statisticians and economists (Fisher, 1922; Mitchell, 1913). Measuring the evolution of economic activity through indices, not only of prices, but also of volumes of production, was a work in progress, especially within the institutionalist circles.[22] In his paper, Tryon does not build his own index of output; he uses indexes proposed by Day (1921), Snyder (1921, 1927) and Stewart (1921).[23] The main correlation drawn between his index of energy and an index of production (Tryon, 1927, 277) is based on Snyder's proposal, which was a classic reference at the time (Burgess, 1946; Garvy, 1978). Snyder was affiliated to the Federal Reserve Bank of New York, and had access to many surveys and data to build his indicator. His project of an "index of business activity" (Snyder, 1924), called later "index of the volume of trade" (Snyder, 1925, 1928), started in the early 1920s. He then published regular updates incorporating new data, and extensive discussion on weighting problems.[24] When Tryon wrote his paper, Snyder had not published all his series yet, but he sent his data to the former before the publication of his volume *Business Cycles and Business Measurements, Studies in Quantitative Economics* in 1927 (Tryon, 1927, 277). With Snyder's unweighted index, and Day's and Stewart's alternative calculations, Tryon (1927, 276–78) had information for the first pillar of his analysis, namely the evolution of activity in the United States since the end of the 19th century.

Concerning the index of energy, he almost had to start from a blank page. Indices of energy prices, or energy companies' stocks, already existed (e.g. Pogue, 1921a), but information on volumes was rare. Constructing a synthetic index of energy was therefore a novelty. One difficulty was the combination of different forms of energy (heat, driving force) in a single framework, as Tryon expresses:

> "An index of power as a factor in production should therefore include heat as well as mechanical power. The two are interchangeable, derived from the same sources, and to an increasing degree supplied by the same agencies. Yet they are sufficiently

[21] Tryon (1927, 271f) explains that he did not get the opportunity to update the data of his paper between the presentation at the conference and the final publication.

[22] Institutionalists have notably been at the origin of the NBER (Rutherford, 2011, 44–45, 265). The debates on the measurement of economic activity were part of broader controversies on business cycle theories, in which Fisher and Mitchell were involved (see Dimand, 2003).

[23] Stewart, in particular, was an important figure of the institutionalist movement.

[24] The weight given to each component of an index could change the results of the observations. As Snyder (1923, 421) points out: "The choice of weights, of material, of the accuracy of the data [...] is of far greater importance, and it is these and not the method of averaging which makes practically all the remarkable differences, for example, which appear at this moment between the different indices of prices in this country".

> distinct so that the ideal index should consist of two series, one representing direct heat, the other mechanical motion, the two being finally combined into a composite index of energy." (Tryon, 1927, 274)

If electricity could be a good proxy in the short-run to estimate the fluctuations of energy uses (ibid. 272), it could not be satisfactory for the long-run, because "it does not go back far enough, and because it still covers only a part of the total amount of power generated" (ibid. 272). A global index of power, including heat and mechanical power, needed therefore to be constructed on new foundations.

According to Tryon, the best indicator for the driving force was "the total number of horsepower-hours generated by all forms of power equipment" (ibid. 273). Tryon used a study prepared by Daugherty (1928), entitled "The Development of Horsepower Equipment in the United States", and not published yet at the moment of his writing.[25] Tryon had access to this paper because he knew Daugherty from a seminar conducted at the University of Pennsylvania during the academic year 1924-1925. In the preface of his 1928 paper, Daugherty explains that he met Tryon at this seminar when he was a student, and that led him to conduct a doctoral research on horsepower equipment. Not only did Tryon orient him on this track, he also continuously followed the preparation of the dissertation. This episode suggests that Tryon had preliminary ideas on the relationship between energy and output before 1926, and that he was early aware of the research needs to address the question. Many arguments, methods and sources are common to Daugherty's and Tryon's studies: their agricultural data come from Kinsman (1925)'s *An Appraisal of Power Used on Farms in the United States*; Daugherty (1928, 40–42) suggests a comparison between the development of mechanical force and economic output, with a reference to Stewart's index; both use graphs to highlight the correlation between economic and energy variables (Daugherty, 1928, 111; Tryon, 1927, 277).

These similarities could suggest that the first ideas of the Brookings energy program emerged independently from the Brookings, at the Pennsylvanian seminar. Like Bain's encouragement, the seminar was probably one impulse among others. Tryon's joint paper with Linda Mann, published in 1926 but written for the 1924 Christmas meeting of the American Statistical Association, also exposed intuitions on the same topic (Tryon and Mann, 1926, 124). In fact Tryon was personally interested in the question even before 1924-1925, as the previously mentioned correspondence with R. S. Brookings testify. Perhaps his original idea came from the book *America's Power Resources: The Economic Significance of Coal, Oil, and Water-Power* by Gilbert and Pogue (1921), in which the cross-sectoral approach of energy is suggested, yet without any measurement of the energy-output relationship. The book was indeed reviewed by Tryon:

> "The authors show that the rapid increase in the mechanical energy at the command of the United States has been the chief element in our material progress. [...] The important contribution of the authors is their insistence on the necessity of viewing coal, petroleum, gas, and water-power as a common source of energy, and their courage in outlining a coordinated plan for energy development." (Tryon, 1922, 146)

In 1926-1927, finalizing his article, Tryon used Daugherty's index of mechanical power to get information for his synthetic index of energy. He had to adjust the data, because Daugherty (1928, 15; 1933, 429) measured the total horsepower equipment in terms of maximal capacity, not of real use. He mobilized an "average use factor" (Tryon, 1927, 273), not specified in the text, to get the accurate information for his analysis.

Once information was collected on the driving force, information on heat generation was needed. According to Tryon, fuel consumption constituted a basis:

[25] Tryon tried to convince Moulton to publish the manuscript under the authority of the Brookings Institution (Letter from F. G. Tryon to H. G. Moulton (Jan. 20th 1927), FGTP, administration file), but apparently he failed, probably because the study had not been conducted at the Institute of Economics. Daugherty (1933) also published an updated version of his study in the *American Economic Review*.

> "The contribution of heat is as indispensable as of many other form of energy. The essential thing is the country's command of energy, and at present about half the annual energy budget – equivalent to 480,000,000 tons of coal – is consumed as heat. We commonly think of heat as used for warming buildings, but a greater amount goes for industrial purposes. The most ravenous consumer of energy is the iron and steel industry, and it requires many times as much energy in the form of heat as in the form of motion." (Tryon, 1927, 274)

A complete index of energy would have required the integration of heat produced from firewood by households, but Tryon confessed that he had to put this variable aside (ibid. 275), certainly because of missing data on the decentralized consumption of wood (Berndt, 1978, 250). The effect of this omission on the results was presented as marginal for the most recent period, but more decisive for the early period (the end of the 19th century), when firewood was "a relatively important source of heat and even power" (Tryon, 1927, 278). In fact, since the main focus of his study was on the agricultural and industrial sectors, we think this omission was not very important in the end.

Tryon would have liked to fully complete the two series of data, on the one hand, for power, and on the other, for heat (ibid. 274). He finally proposed a single synthetic series of "the raw energy consumed for all purposes" (ibid. 274), with a thermal equivalence expressed in British thermal units (BTU), by the conversion of his information on horsepower equipment into quantities of fuel (coal) needed to produce the same amount of energy.[26] In early writings, Tryon already focused on BTU for economic activity, stating that consumers were not interested in the energy mix, or in the origin of power, but in the ratio BTU/dollars spent:

> "The conservationist can advance excellent reasons why the use of oil under steam boilers should be discouraged as a matter of national policy, but the consumer, watching his bills, is going to select his fuel on the basis of dollars and cents. His problem is to find the best bargain in B.T.U.'s." (Tryon, 1920, 506)

It is therefore not surprising to see Tryon using BTU at the foundation of his index, even if he also used other units (kWh) in later studies partly related to the Brookings energy program (Nourse et al., 1934, 318).[27]

3.2. The relationship between energy consumption and economic output

To highlight the relation between his index of energy and Snyder's index of production, Tryon (1927, 277) draws a large logarithmic graph with a curve for each index, 1899 being the reference year (index = 100). The correlation of the two trends is depicted as "fairly clear" (ibid. 278) for the whole period. Both energy consumption and economic output grow steadily. On average, energy consumption grows faster than output:

> "Whereas the physical volume of production has been found to increase at the rate of something like 4 per cent a year, the consumption of energy over much of the period shown was compounding at the rate of from 5 to 7 per cent a year." (Tryon, 1927, 278)

The movements of the first curve are reproduced on the second curve with similar magnitude. The only difference in the shape of the curves appears in the long period: the production curve has a smooth shape (from the index ca. 56 to the index ca. 260), while the energy curve seems to flatten in the late period after a boom at the beginning (from the index ca. 18 to the index ca. 305).[28] This impression is

[26] Tryon (1927, 276) had to take care of the converting factors. For instance, he explains that, because of unflattering returns, "the horsepower-hours of animal power [...] have been converted into equivalent fuel, assuming a very low thermal efficiency". He certainly worked with Daugherty on this topic, whose interest in animal power also appears in the 1928 essay (ibid. 16, 20, 33). Interestingly, his approach was the opposite of the one most often used today, where primary sources are converted into useful energy (to account for losses).

[27] The use of BTU as a yardstick for all forms of energy is also evoked in Tryon and Mann (1926, 123f) and Tryon (1929, 8).

[28] Obviously, these remarks need to be mirrored with the logarithmic scale of the graph, which disturbs the visual representation of the trends.

confirmed by Tryon, who dates the starting point of the "pronounced flattening of the trend" (ibid. 278) to World War I, precisely 1917. In other words, there is a global correlation between the two indices over the long period, but the relationship seems different prior to and after 1917: energy consumption grew relatively faster than production before 1917, and slower thereafter. According to Tryon, the explanation is to be found in the fuel efficiency gains obtained in the late 1910s and 1920s, thanks to technical progress and resource substitution, stimulated by energy prices in wartime. The impact of these high prices was one of the concerns of the Brookings, and more broadly of the institutionalist movement, because it induced overcapacities in the oil, coal and gas sectors, seen as responsible for the economic and social difficulties of the energy industries in the 1920s and early 1930s (Nourse et al., 1934; Tryon, 1929; Tryon and Allin, 1936). In his 1927 article, Tryon does not believe that further efficiency gains are possible:

> "It is not expected that progress in fuel economy can continue indefinitely at its present rapid rate, and in time the growth of energy consumption may be expected to resume a course more nearly parallel with that before the war." (Tryon, 1927, 278)

This means that the most recent period is rather seen as a parenthesis than as a new enduring state; the normal trend for the industrial era is a situation where energy intensity is stable. Actually, Tryon somehow revised his position in further contributions. In 1933, with Margaret H. Schoenfeld, he admitted that "[...] technology and its allies have been winning over the growing natural difficulties of mining" (ibid. 75), that "the rate of increase [of the consumption of fuel] has slowed down since the war and [that] there is reason to think that it will be less rapid in the future" (ibid. 60).

By emphasizing the statistical (graphical) correlation between energy and output for the whole period, and by describing the relative disconnection between his variables after the mid-1910s, Tryon completed his empirical observations. He then had to address the articulation of these observations with economic theory. On this point, after his initial claim for "the reconnaissance [...] of power as a factor of production" (Tryon, 1927, 271), the rest of his analysis does not quite match the ambitions. Tryon does not precisely address the theory of production, whether through production functions or other types of representation. If the absence of production functions is certainly due to Tryon's proximity to institutionalism – institutionalists were skeptical about such formalisms (Rutherford, 2011, 317) – the lack of alternative proposals for the theory of production raises questions.

We identify two hypotheses that might explain this. First, Tryon could have considered that his empirical results were sufficient to prove the explanatory role of energy in development, using observations to describe stylized facts. If true, this attitude would not have escaped the criticism often directed in the interwar period by neoclassical authors at institutionalists for limiting themselves to empirical observations (Rutherford, 2011, 151). Second assumption: Tryon could have considered his 1927 paper as a first step in his theoretical project, announcing other studies more directly addressing the theory of production. Unfortunately, there is no trace of such theoretical attempts in the subsequent works related to the Brookings energy program. [29] Perhaps Tryon's institutionalist colleagues did not found deep interest in carrying out a theoretical analysis so disconnected from realities.[30] 'Energy' was already an encompassing category, a little above ground. Integrating it into an abstract theory of production would have created a distance that may have been too far from the real world. If this second hypothesis is true, it means that Tryon may not have fully positioned himself as an

[29] We could have expected, for instance, a reaction from Tryon to the publication of Cobb and Douglas (1928, 165)'s article on the production function, in which the authors briefly discuss the consideration of natural resources as a "third factor" of production. We thank Quentin Couix for drawing our attention on this point.

[30] Hamilton, for instance, as one of the founders of the institutionalist movement, was not so interested in building a set of theoretical economic principles. He privileged practical situations (Rutherford, 2011, 184).

institutionalist – none of his texts provides explicit guidance on this point – but that the institutionalist context weighed on the incompleteness of his project.[31]

There is nevertheless one theoretical point mentioned by Tryon, i.e. the question of causality between the correlated variables: if the increase in energy consumption causes the growth of production, then energy is an explanatory factor of growth, and can therefore be considered as a factor of production. In fact, concluding on causal relationships based on correlations is a classic problem, of which Tryon was obviously aware. As Ayres (2001, 822–23) reminds us, “the linkage [between energy and output] goes in both directions, of course[; o]ne cannot say a priori which is the cause of the other (or, in fact, whether both are joint consequences of another cause)”. In his 1927 article, Tryon reports on this dual reading of his results:

> “The broad relationships are unmistakable. A great increase in per capita production is made possible by a still greater increase in power, and along with the process goes an increase in transportation which is the greatest of all consumers of power.” (Tryon, 1927, 279)

If production “is made possible by” energy, it suggests that energy drives economic output, and not the other way round. But the loop seems to be closing once certain sectors also fuel energy consumption.

Tryon observes a statistical “lag” between “the adjusted energy index” and “the adjusted index of manufactures” (ibid. 281) when he compares his series with Day's data. Energy consumption seems correlated to “the physical volume of manufactures” (ibid. 280) with a little delay. We know that Tryon did not have the statistical tools to make a full treatment of these lags.[32] Yet he was sufficiently equipped to know that the existence of such lags had no decisive significance for causality – they can be explained by many factors, including data reporting. In his text, Tryon confesses that he does not know how to explain the lag he is observing:

> “Why there should be a lag, I am not prepared to say, but the data suggest that the full response to a given boom or depression is registered somewhat later in the total consumption of energy materials than it is in the volume of manufactures as measured by Professor Day.” (Tryon, 1927, 281)

Tryon's project to recognize energy as a factor of production was not fully completed, but it highlights that behind empirical observations, economists involved in the issue of coupling or decoupling quickly find themselves trapped in the causal question, and indirectly in theoretical issues related to the representation of production.

As mentioned, in addition to empirical foundations and theoretical ambitions, the Brookings energy program sought to provide policy-relevant proposals. Tryon's 1927 article is rather silent on this point, mentioning only the role of federal authorities in surveying activities across the country (ibid. 275). It is in other contributions that the Brookings experts addressed the subject, promoting national and cross-sectoral energy policies. Echoing an early text by Tryon (1924b, 172) stating “we need a national policy of fuels and power”, Tryon and Schoenfeld (1933, 88) deplore that “until means are found to coordinate policies among the principal producing states [of fossil fuels] the problem of waste prevention will remain unsolved”. In their inventory of America's productive capacities, Nourse et al. (1934, 314f) also refer to the “national consumption of energy in all forms” when examining the organization of power utilities at the federal level.

The articulation between empirical concerns, economic theory and energy policy is an interesting feature of the Brookings energy program, which remains relevant today in our reflections to conceptualize, measure and monitor decoupling, in order to have a global understanding of the issues at stake.

[31] Obviously, Tryon shared several of the institutionalist viewpoints, in particular on the consistency between empirical observations and theoretical proposals, and on the role of regulation in business activity. He however showed less attachment to other pivotal questions such as bounded rationality.

[32] Even if Fisher (1925, 1937) sketched some original idea about distributed lags (see Goldberger, 1964), the first systematic treatments were by Koyck (1954), Nerlove (1958) and Dhrymes (1971).

4. An econometric assessment

At the very end of his article, Tryon (1927, 282) provides raw data about his index of energy, for the period 1899-1926. This offers an opportunity to examine his calculations with some econometrics.[33] Our objective is not to overturn Tryon's conclusions on the mid-run relationship between energy consumption and economic output, which have been retrospectively judged as fairly valid (Barnett, 1950; see Berndt, 1978). It is to numerically estimate his graphical results, to provide more detailed information regarding his two periods (before and after 1916-1917), and to test the statistical corrections he made for exogenous shocks (war and strikes) using more transparent methodologies than his own (Tryon, 1924a, 82; Tryon, 1924b, 163; Tryon, 1927, 275, 280–81; Tryon, 1936a, 305). On this last point, Tryon (1927, 279) firstly made a correction "for the growth trend" to erase the tendency – this was a classic manipulation at the time to highlight potential correlations – and then he made arbitrary adjustments for the years 1900, 1901, 1902, 1903, 1911 and 1912 in order to take into account the impact of strikes (ibid. 281f). His adjusted series of data is reproduced in the final table of the paper (ibid. 282). For our assess-ment, we set aside this adjusted index and focused on the raw data (see Appendix).

Regarding production, Snyder's index is not disclosed in Tryon's paper, but information can be found (for the period up to 1925) in Snyder (1927)'s *Business Cycles and Business Measurements, Studies in Quantitative Economics*. "Appendix - Table 3" (ibid. 239) of the book is entitled "Production Indexes (Snyder)" and contains two series: one with 49 components, the other with 87 items. In his analysis, Tryon (1927, 277) mentions a "physical volume of production [...] includ[ing] a varying number of items, beginning with 49 in 1870 and increasing to 86 in 1910" (ibid. 277).[34] There is no trace in Snyder's book of such an index with an increasing number of components. Yet the two series (49-items and 87-items) are similar for the early period, and the data used by Tryon for the later period (as they appear in the graph (ibid. 277)) seem to correspond to Snyder's 87-items series. Perhaps Tryon got access to other preliminary works by Snyder; we did not. So we computed tests with the two series (49- items and 87-items), also to see if any differences appear (see Appendix).

Our estimates are specified in logarithms as is standard in the literature on the energy-output relationship. This allows their direct interpretation as elasticities, regardless of the nature of the raw data (physical quantities, monetary values or index sets). The first specification is a static model representing a mid-run relation between energy and production indexes from 1899 to 1925. We performed a Chow test for a time series rupture in 1916 or 1917. Variables are labeled: 't' for time, 'E' for Tryon energy index, 'S49' and 'S87' for Snyder's 49-items and 87-items indexes, 'Coal' for the coal strikes dummy (equal to 1 for years with a coal strike, 0 either), 'War' for the years 1914-1918.[35] We estimated all the equations with robust standard errors (HAC estimators with Bartlett kernel of bandwidth 2).

Static log of energy and Snyder's 49-items indexes:

$$\ln E_t = \underset{(0.0222)}{-0.0729} + \underset{(0.00446)}{0.0465}t - \underset{(0.0001)}{0.0012}t^2 + \underset{(0.1091)}{0.9295} lnS49_t - \underset{(0.0109)}{0.0189} Coal - \underset{(0.0217)}{0.0507} War \quad (1)$$

$$R^2 = 0.9826 \quad see = 0.0419 \quad DW = 2.3475 \quad Omibus\,\chi^2(2) = 3.473$$
$$Breuch-Godfrey\,\chi^2(1) = 1.0480 \quad White\,\chi^2(16) = 11.9832$$
$$Chow(1916)\,\chi^2(6) = \mathbf{77.9665} \quad Chow(1917)\,\chi^2(6) = \mathbf{120.2}$$

Standard errors of coefficients are given in the second line. The regression statistics include: corrected R2, standard errors of regression ('see'), Durbin-Watson statistic, Hansen Doornik

[33] We limited ourselves to basic tools, since sophisticated ones would have been irrelevant because the sample is small. Co-integration tests, subject to slow convergence, could be relevant for Tryon's long series, from the 1870s to the 1920s, but missing data would have to be approximately read on the logarithmic graph (Tryon, 1927, 277), without the same degree of precision. We preferred to base our assessment on available reliable data.

[34] Tryon surprisingly characterizes Snyder's largest series as composed of 86 items (instead of 87).

[35] Major coal strikes are dated 1900, 1902, 1906, 1912 and 1919.

omnibus normality test, Breuch-Godfrey test, first-order autocorrelation test and White heteroscedasticity test. Chow structural stability tests were conducted for 1916 and 1917. Falsified tests have their statistics in bold. We can see that for Eq. (1) the structural stability of coefficients is strongly rejected both for 1916 and 1917, which shows a break. If we turn to Snyder's 87-items index, the equation is as follows:

Static log of energy and Snyder's 87-items indexes:

$$\ln E_t = -\underset{(0.0262)}{0.0845} + \underset{(0.0052)}{0.0444t} - \underset{(0.0001)}{0.0012t^2} + \underset{(0.1193)}{0.9512 lnS87_t} - \underset{(0.0138)}{0.0358 Coal} - \underset{(0.0138)}{0.0452 War} \quad (2)$$

$$R^2 = 0.9856 \quad see = 0.0381 \quad DW = 1.696 \quad Omibus\,\chi^2(2) = 3.24$$
$$Breuch-Godfrey\,\chi^2(1) = 0.5432 \quad White\,\chi^2(16) = 12.68$$
$$Chow(1916)\,\chi^2(6) = \mathbf{33.62} \quad Chow(1917)\,\chi^2(6) = \mathbf{67.086}$$

The conclusion is the same: a structural break occurs in 1916-1917, with a pronounced break at the start of the US military operations in 1917.

In both Eqs. (1) and (2), there are significant effects of coal strikes and war dummies, showing a decrease of energy consumption due to the effects of these shocks on production. Elasticities vary from 0.93 (Snyder's 49-items index) to 0.95 (Snyder's 87-items index). Static equations estimated without trends (not displayed here) show similar results with higher elasticities: 1.38 and 1.23 respectively for Snyder's 49-items and 87-items series. Addition of a quadratic time trend lowers the static long-run elasticities in this specification. We then estimate an auto-regressive distributed lag of order 1 in both dependent and explanatory variables. This 'ARDL(1,1)' model allows the computation of short-run and long-run elasticities derived from the model.

ARDL(1,1) with log of energy and Snyder's 49-items indexes:

$$\ln E_t = \underset{(0.0258)}{0.0705} + \underset{(0.1697)}{0.4377} \ln E_{t-1} + \underset{(0.0827)}{0.8113 lnS49_t} - \underset{(0.2618)}{0.0642 lnS49_{t-1}} - \underset{(0.0162)}{0.0220 Coal} - \underset{(0.0201)}{0.0011 War} \quad (3)$$

$$R^2 = 0.9643 \quad see = 0.0557 \quad h = -0.4996 \quad Omibus\,\chi^2(2) = 1.444$$
$$Breuch-Godfrey\,\chi^2(1) = 0.1387 \quad White\,\chi^2(16) = 11.4235$$
$$Chow(1916)\,\chi^2(6) = \mathbf{157.625} \quad Chow(1917)\,\chi^2(6) = \mathbf{367.032}$$

The estimated equation also shows a structural break, both in 1916 and 1917. The break is far stronger in the year 1917. The speed of adjustment indicated by the coefficient of the lagged dependent (0.4377) is low but significant. The short-run elasticity of Eq. (3) is equal to 0.8 and the long-run elasticity is equal to 1.33, being computed as the sum of the short-run elasticities divided by the complement to 1.0 of the adjustment speed of the lagged dependent. With Snyder's 87-items series, the equation is:

ARDL(1,1) with log of energy and Snyder's 87-items indexes:

$$\ln E_t = \underset{(0.0230)}{0.0585} + \underset{(0.1292)}{0.6702} \ln E_{t-1} + \underset{(0.0818)}{0.9058 lnS87_t} - \underset{(0.2045)}{0.5392 lnS87_{t-1}} - \underset{(0.0162)}{0.0402 Coal} - \underset{(0.0207)}{0.0035 War} \quad (4)$$

$$R^2 = 0.9709 \quad see = 0.0502 \quad h = -0.5091 \quad Omibus\,\chi^2(2) = 0.09$$
$$Breuch-Godfrey\,\chi^2(1) = 0.3703 \quad White\,\chi^2(16) = 14.474$$
$$Chow(1916)\,\chi^2(6) = \mathbf{181.568} \quad Chow(1917)\,\chi^2(6) = \mathbf{187.935}$$

The estimates of Eq. (4) differ from those of Eq. (3) but have the same statistical properties. What is different is the speed of adjustment, which is slightly higher: 0.67 instead of 0.43, showing a longer delay of adjustment of about two years instead of one. The short-term elasticity, sum of the coefficients of the logs of Snyder's 87-items index, is low (0.36). Both coefficients are significant. The long-run elasticity is 1.11, somewhat lower than with Snyder's 49-items index. Under Eq. (4) the structural breaks are of the same magnitude in 1916 and 1917.

The relative disconnection noticed by Tryon after World War I is confirmed in both specifications.[36] The main confirmation is the existence of a relationship between energy and manufacturing production, seemingly affected by the beginning of US operations in WWI. Both the static and dynamic models show a rupture for 1916 and 1917, confirming Tryon's findings.

This econometric assessment does not overturn Tryon's conclusions, but it helps characterize the relationship between energy and

[36] We do not provide the results of Eqs. (3) and (4) for the sub-periods 1899-1915 and 1916-1925, as they are unreliable.

output from 1899 to 1925, with precise estimates for the elasticities (even if the long-run relation is unstable), and results confirming the 1916-1917 break. We also provide a more transparent view of data adjustments: Tryon opted for arbitrary corrections; our binary option is less dependent on these opaque choices.

Further tests on the long series, from the 1870s to the 1920s, would deserve attention, if Tryon's data for the period prior to 1899 were obtainable – approximations from his logarithmic graph might be conceivable. More broadly, the characterization of Tryon's statistical choices in the methodological controversies of the 1920s would be an interesting subject of investigation. This particular question is beyond the scope of the current paper, but would be worth of interest with respect to the history of statistics and econometrics.

5. Conclusion

The Brookings energy program has been an uncommon research experience, at the intersection of academia, expertise and politics, in the context of the interwar American institutionalism. From a historiographical point of view, this episode provides new insights regarding the history of resource and energy economics. Alongside the development of a neoclassical approach, from Gray to Hotelling, the institutionalist movement developed a separate expertise, rooted in the practical situations of the oil, coal and waterpower sectors. At the Brookings Institution in the late 1920s, this expertise was characterized by early consideration of energy as a whole, whatever its forms and uses.

Frederick G. Tryon, who defined himself as a mineral economist, launched a project which can retrospectively been considered as pioneering: the measurement of the correlation between energy consumption and economic output. His background as a geologist, economist and statistician at the US Geological Survey makes it difficult to know if he considered himself an institutionalist. What is certain is that his work fully took place in the institutionalist context, and that he had institutionalist acquaintances with colleagues at the Brookings Institution. The characteristics of his global project (empirical foundations, theoretical ambition, policy relevance) and his interest in regulation were in line with the institutionalist program.

Tryon's empirical endeavor was a success, insofar as his calculations, based on Daugherty, Snyder, Day and Stewart, did highlight the correlation between energy and output. Our econometric assessment confirms Tryon's 1927 statements, and completes some of his results with detailed figures on the basis of transparent methodologies.

The theoretical ambition – the recognition of energy as a factor of production – was not fully achieved. Tryon did not provide a complete representation of the theory of production including energy as an essential element.[37] In his 1927 contribution, he tackled the problem of causality, but ran into classic questions about the interpretation of correlations. It seems that he failed to mobilize his Brookings colleagues on his ambitious theoretical project, perhaps because this project was too above ground in the institutionalist context. Also, as mentioned in the introduction, the main concern at the time was not energy conservation, but the social question induced by the substitution of human and animal working-force by mechanical power. We can explain the more moderate support for the energy program after 1932 (publication of *Mineral Economics*) by the pre-eminence of these social questions, reinforced by the Great Depression – the Brookings Institution certainly had other priorities in the 1930s.[38]

Finally, with respect to the policy relevance, the success was also incomplete. Tryon et al.'s participation in a few reports and public enquiries until the mid-1930s suggests that their proposal to conceive energy policy as national and cross-sectoral was of interest for public authorities. But the unification of energy policies

[37] Reflections in this direction developed in economic thought essentially from the 1970s onwards. See Couix (2020).

[38] Tryon's correspondence from the summer of 1934 suggests that he had finished his missions at the Brookings Institution. His departure did not seem final at the time, but the archives do not contain any trace of further in-depth collaborations (FGTP, administration file).

in the US only occurred in the 1970s, with the creation of the Department of Energy in 1977 and the elaboration of the National Energy Act package the following year.

The lessons of this episode are that, when considering the role of energy in economic development, we should pay attention to empirical, theoretical and political dimensions of the issue. The very specialized, sometimes compartmentalized, character of contemporary research and expertise makes it difficult to have a global view of decoupling issues. The institutionalist perspective, illustrated by this 1920s-1930s, shows that systemic approaches can be fruitful and innovative to address the pressing challenges of sustainable development and of the climate crisis. Empirical observations need to be sustained by new theories of production and growth, and prolonged by political implications.

Another teaching is that energy topics are essentially multidisciplinary, and that the cooperation between economists, geologists, engineers and other scientists is insightful to address the relationship between energy consumption and economic output.

Tryon's project has remained unfinished; it is still relevant today in all its dimensions (empirical, theoretical and political) to see the extent to which energy can be considered a factor of production, and to draw all the consequences in our economic representations and in our energy choices.

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Archives

FGTP: Frederick G. Tryon Papers, Brookings Library, Brookings Institution Washington DC.

HHP: Harold Hotelling Papers, Rare Book and Manuscript Library, Columbia University.

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Appendix | Table:
Tryon's index of energy and Snyder's indexes of production

Year	Tryon's index of energy (unadjusted)	Snyder's index of production (49-items)	Snyder's index of production (87-items)
1899	100.0	100.0	100.0
1900	106.6	102.2	106.6
1901	115.8	114.2	116.8
1902	122.4	120.8	126.7
1903	140.5	125.4	128.1
1904	140.7	128.4	128.3
1905	156.5	129.4	135.1
1906	164.4	138.7	147.3
1907	190.0	140.9	149.3
1908	169.5	137.5	133.4
1909	186.6	144.3	148.4
1910	203.3	149.6	157.2
1911	199.8	148.2	154.5
1912	216.2	158.5	166.4
1913	228.3	159.1	171.8
1914	211.2	160.8	166.8
1915	217.9	172.6	179.3
1916	249.6	188.3	203.3
1917	269.0	198.8	214.5
1918	270.7	195.7	204.8
1919	252.2	184.7	198.6
1920	270.7	194.6	210.5
1921	226.8	159.5	181.0
1922	238.4	194.1	210.0
1923	296.8	213.9	235.2
1924	281.7	209.6	230.5
1925	287.8	222.2	244.3
1926	310.0	/	/

Source: Tryon 1927, 282; Snyder 1927, 239. Note: Snyder's indexes were originally computed on a base of 1910-1914 (average) equals 100. As Tryon did, we converted Snyder's series to base 1899 equals 100.