

Shifts in Canonized Economic Knowledge:
A Quantitative Assessment of *Economics* à la Paul
Samuelson and William Nordhaus (1948-2010)

Rainer Klump*, Marius Liebold†, Ingo Sauer‡, and Pascal Wolf§

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Abstract

We examine shifts in the importance and connotation of focal economics concepts over the second half of the 20th century. Our study relies on quantitative text and sentiment analyses of the 19 editions of Paul A. Samuelson’s textbook *Economics*. Its longevity and its global commercial success have made it a valuable source for detecting long-term developments of mainstream economic knowledge. Our paper complements existing qualitative and cross-sectional quantitative studies on *Economics* with a time series perspective. We can generally confirm findings from earlier qualitative research but give them a quantifiable and thus more precise meaning.

JEL Classification: A00; A22; B00; B40

Keywords: Introductory Economics, Mainstream Economics, Quantitative Text Analysis, Sentiment Analysis, Topic Modeling, Schools of Economic Thought

*Department of Economic Policy and Quantitative Methods, Goethe University Frankfurt, Theodor-W.-Adorno Platz 4, 60323 Frankfurt, Germany. Corresponding author. Phone: +49 69 798 34782, E-Mail: klump@wiwi.uni-frankfurt.de. This work received funds from the Hessian Ministry of Higher Education, Research, Science and the Arts through a global research grant provided to the Cluster of Excellence “Normative Orders” at Goethe University Frankfurt. Additionally, we thank Wendy Carlin for providing access to their topic model.

†Department of Microeconomics & Management, Goethe University Frankfurt, Theodor-W.-Adorno Platz 4, 60323 Frankfurt, Germany. Phone: +49 69 798 34819, E-Mail: liebold@econ.uni-frankfurt.de

‡Department of Economic Policy and Quantitative Methods, Goethe University Frankfurt, Theodor-W.-Adorno Platz 4, 60323 Frankfurt, Germany. Phone: +49 69 798 34781, E-Mail: isauer@wiwi.uni-frankfurt.de

§Department of Economic Policy and Quantitative Methods, Goethe University Frankfurt, Theodor-W.-Adorno Platz 4, 60323 Frankfurt, Germany. E-Mail: pascal.wolf15@gmail.com

1. Introduction

The field of economics has repeatedly experienced shifts in its dominant paradigms. The spreading of a new paradigm starts in distinct academic circles that later become known as a particular school of economic thought. The paradigm's wider influence then relies on its impact on the education of the next generation of scientists, practitioners, and politicians. Therefore, any new economic paradigm must strive for the canonization of its basic insights to become mainstream knowledge. Teaching such a canon to future decision-makers helps to form their perception of economic phenomena and appropriate options for effective policy interventions. The canon remains stable until unexplainable phenomena and crises call for a drastic revision or even dismissal of the dominant paradigm.

Introductory textbooks play a central role in the canonization of scientific paradigms (Vicedo, 2012). By collecting and presenting state-of-the-art knowledge, they lay the theoretical foundation for students in the field and influence people outside the research circles. Consequently, revealing major shifts in scientific paradigms through a close look at the evolution of the content in introductory textbooks might help explain the changing natures of implemented economic policies over time.

Economics by Paul A. Samuelson, co-authored by William D. Nordhaus since 1985, is a showcase for a highly influential textbook in the second half of the 20th century. Its importance compares to the works of David Ricardo, John Stuart Mill, and Alfred Marshall (Skousen, 1997). *Economics* stands out by not only its extreme longevity but also its remarkable commercial success. The author(s) published 19 editions between 1948 and 2010 (see Table 1 for the publication year of each edition) that were bestsellers in both the US and international markets. For instance, translations into more than 50 languages illustrate the textbook's global success. Sales peaked in the middle of the 1960s, with about 167,000 books sold alone in 1964 (Elzinga, 1992). Nelson (2001, p.16) calls the textbook “[t]he closest thing to a bible of economics during the several decades after World War II”.

Table 1: The 19 Editions of *Economics*

<i>Economics</i> Edition	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Year	1948	1951	1955	1958	1961	1964	1967	1970	1973	1976	1980	1985	1989	1992	1995	1998	2001	2005	2010

Note: This table provides information on the publishing years (lower row) of the 19 *Economics* editions (upper row).

In light of these facts, analyzing dynamics in the content of *Economics* should reveal shifts in the canon of *mainstream economics*. Whereas qualitative assessments of the dynamics in *Economics* have been conducted (e.g., Giraud,

2014, 2018, 2020), comprehensive analyses relying on appropriate quantitative techniques that cover all 19 editions are still absent from the literature.

This paper addresses this gap. We conduct sentiment analyses and key expression count exercises and take advantage of Bayesian machine-learning techniques to identify major turning points in the 19 editions of *Economics*. In doing so, we account for shifts in coverage and sentiment of individual economic concepts, topics, and schools of thought. Our findings are largely in line with qualitative assessments. For instance, we quantify the massive increase in the coverage of the Chicago School in the 12th edition by showing that the usage of associated key expressions had quadrupled compared to previous editions.

We view this paper’s time series perspective to complement a study by Bowles and Carlin (2020), who follow a cross-sectional approach when comparing the contents of different economics textbooks. Moreover, our study moves along the lines of Edwards et al. (2018), who view quantitative techniques to have become an inspiring toolset for studies in the history of economic thought.

We will proceed as follows: Section 2 reviews the existing literature on the content and impact of *mainstream economics* à la Samuelson/Nordhaus. Section 3 gives a qualitative overview of the textbook’s evolution. Section 4 then sets out our quantitative approach, explains the tools of our textual analysis, and discusses the results. Section 5 summarizes and concludes.

2. Literature Review: *Mainstream Economics* and its Impact

Paul A. Samuelson (1915-2009) himself, winner of the Nobel Memorial Prize in Economic Sciences in 1970, introduced the concept of a canon in economics when referring to a “canonical classical model of political economy” (Samuelson, 1978, p.1415). He uses this term to label specific concepts of equilibrium, growth, and distribution that he saw explicitly or implicitly present in the works of Smith, Ricardo, Malthus, Stuart Mill, and even Marx. When speaking about this canonical model and its “codification”, Samuelson uses the expressions “minimal essentials” and “oversimplification”. We conjecture that he would accept using the same expressions when assessing his introductory textbook, including the laid-out economic canon.

In the preface to the 3rd edition of *Economics* in 1955, Samuelson introduces the famous concept of a *neoclassical synthesis*. Under this term, he refers to a concept of economics that unites classical economic principles with, at that time, new insights to form canonized knowledge. In the 7th edition, Samuelson (1967, p.196) describes this synthesis as “[...] accepted in its broad outlines by all but a few extreme left-wing and right-wing writers”. In the preface to the 12th edition, Samuelson and Nordhaus (1985, p.vii) address a *new synthesis* and coin the notion of *modern mainstream economics* “that gives scrupulous attention to all the competing schools of economics: Post-Keynesian Eclecticism, Monetarism, Rational Expectations, Chicago Libertarianism, Marxism, and Radical Economics”.

Starting in 1989, Samuelson and Nordhaus repeatedly state in the pref-

aces that the textbook “[...] has served as the standard bearer for the teaching of introductory economics in classrooms in America and throughout the world. Each new edition has distilled the best thinking of economists about how markets function and about what countries can do to improve peoples’ living standards. [...] Our task [...] is this [...] to present a clear, accurate, and interesting introduction to the principles of modern economics and to the institutions of the American and world economy. Our primary goal is [...] to emphasize the basic economic principles that will endure beyond today’s headlines” (Samuelson and Nordhaus, 1992, p.xv). The last edition of 2010 includes a programmatic statement labeled *centrist proclamation*, which views the authors’ position as equally distant from extreme libertarian and socialist perspectives: “Economic history confirms that neither unregulated capitalism nor overregulated central planning can organize a modern society effectively. The follies of the left and right both mandate centrism” (Samuelson and Nordhaus, 2010, p.xvi).

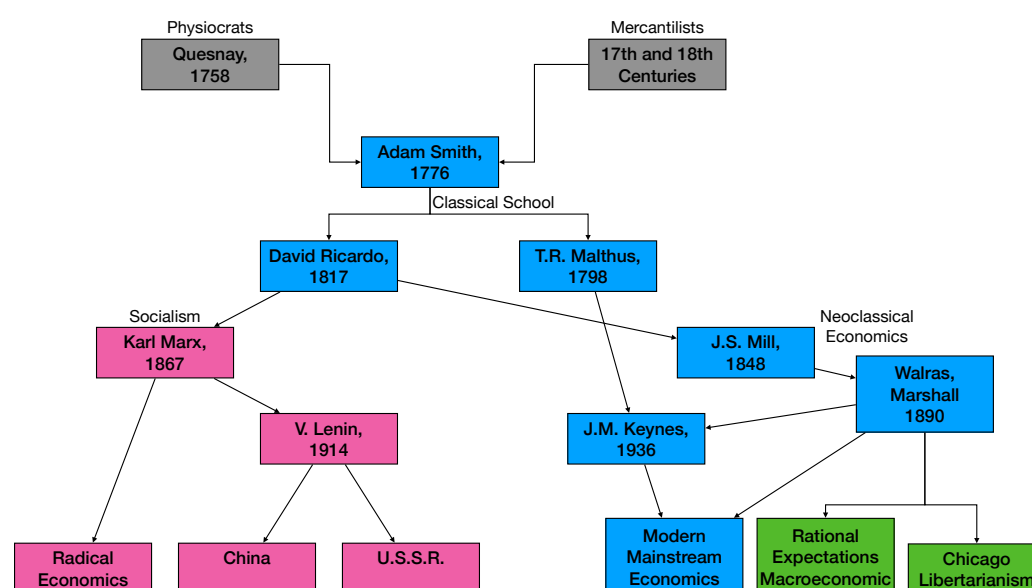
Essential developments in economics and its policy applications characterize the six decades between 1948 and 2010. While the 1950s and 1960s witnessed the global rise of Keynesian economics, Neoclassical Economics and Chicago School positions began to challenge the Keynesian paradigm in the 1970s. Additionally, Marxian and Radical Economics temporarily gained importance in the academic discourse in the late 1960s and early 1970s. Aside from this, economists occasionally remembered Classical Political Economy insights throughout the decades. In light of these developments, we investigate the content dynamics over the 19 editions of *Economics*.

The evolution of the content of *Economics* is well researched. However, most, if not all, studies are qualitative. Brazelton (1977) is at the origin of this research. He compares the 1st with the 9th edition of *Economics* and concludes that “Samuelson works within the framework of a changing and pragmatic Keynesianism” (Brazelton, 1977, p.117). Elzinga (1992) analyzes the textbook’s content up until the 12th edition. He remarks that, “[i]f the chronology of the Samuelson textbook is a reflection of the activity of economists, what the [...] editions reveal is a slightly decreasing emphasis on macroeconomics, with a shift from unemployment to inflation problems and a tilt from fiscal to monetary policy”. Furthermore, he finds that “[t]here is increasing emphasis on microeconomic analysis, both in terms of offering up the theoretical tools of price theory and the applications of these tools” as well as that “[t]here is a decreasing emphasis on institutional material, reflecting the greater scientific character of the discipline” (all quotes are from Elzinga, 1992, p.873).

In 1997, the year the 15th edition was published, Skousen (1997, p.150) states that Samuelson “offered a balanced brand of economics that found mainstream support”. Nonetheless, Skousen (1997, p.150) further acknowledges changes over time as “Samuelson (especially in the earlier editions) favored heavy involvement in ‘stabilizing’ the economy as a whole, [while] he appeared relatively laissez faire in the micro sphere, defending free trade, competition and free markets in agriculture”. Furthermore, Skousen (1997, p.150) views

Samuelson to be generally supportive of market solutions unless they fail, leading to “situation[s] where government intervention could be justified”.

Giraud (2019) refers to *Economics* as the perfect example to evaluate the importance of textbooks in academics and beyond. He also underlines that Samuelson had set standards in the choice of content, the pedagogical approach, and the mode of presentation that most other economic textbooks followed. Moreover, Cherrier (2014) and Giraud (2014) view *Economics* to have helped the MIT gain a broad reputation for its new economics department. In his conclusion, Giraud (2019, p.149) states that “textbooks do not just disseminate knowledge, but by altering it, contribute to create new meanings and uses of preexisting economics ideas”.



Note: This figure illustrates the 1989 version of Paul Samuelson’s *Family Tree of Economics* taken from the back endpaper of the 13th edition of *Economics*. Samuelson and Nordhaus (1989, p.824) divide the schools of economic thought into broad categories, with Adam Smith’s *The Wealth of Nations* from 1776 marking “the birthdate of modern economics”. From that point in time, the author(s) distinguish between *Classical Economics* and *Neoclassical Economics* (both highlighted in blue), their modern critiques (illustrated in green), and Socialism (highlighted in pink).

Figure 1: The Family Tree of Economics

Starting with the 4th edition of 1958, Samuelson includes a graphical illustration of a *Family Tree of Economics* in the textbook. Figure 1 exemplarily illustrates the 1989 version of the family tree, included in the textbook’s 13th edition. The lowest blue rectangular of the tree represents Samuelson’s paradigmatic position. Initially labeled *New Economics*, the name was first changed to *Post-Keynes Mainstream Economics* before Samuelson and Nordhaus referred to it as *Modern Mainstream Economics*. Giraud (2020) regards Samuelson’s emphasis on the mainstream notion as a reaction to attacks from radical economists who had started to criticize his textbook heavily by the end of the 1960s. Backhouse (2016) draws two inferences from the structure

of Samuelson's *Family Tree of Economics*. First, it clarifies that Samuelson acknowledges the existence of competing paradigms in economics. Second, it establishes a clear hierarchy among them, according to which alternative approaches surround a dominant mainstream paradigm at the center. The alternatives to the left comprise the radical economists and Leninists in the Soviet Union and China. To the right, the members of Chicago Libertarianism and proponents of Rational Expectations Macroeconomics offer alternatives to the mainstream perspectives.

Bowles and Carlin (2020) are the first to assess the textbook's content using quantitative text analysis methods. Following a cross-sectional approach, they compare the first edition of Samuelson's *Economics* to four other economics textbooks, including CORE (2017), Ely et al. (1930), Mankiw (2018), Krugman and Wells (2015), as well as the 16th edition of *Economics* from 1998. Their results reveal significant differences in topic coverage across economic textbooks. Most notably, while Samuelson (1948) focuses on topics such as *banking and institutions* and the Keynesian macroeconomic topic *aggregate demand*, Krugman and Wells (2015) and Mankiw (2018) put higher emphasis on *competition and market structure*. Moreover, Bowles and Carlin (2020) compare the counts of analytical figures across textbooks, exhibiting an overall increase over time characterized by varying importance of supply and demand graphs.

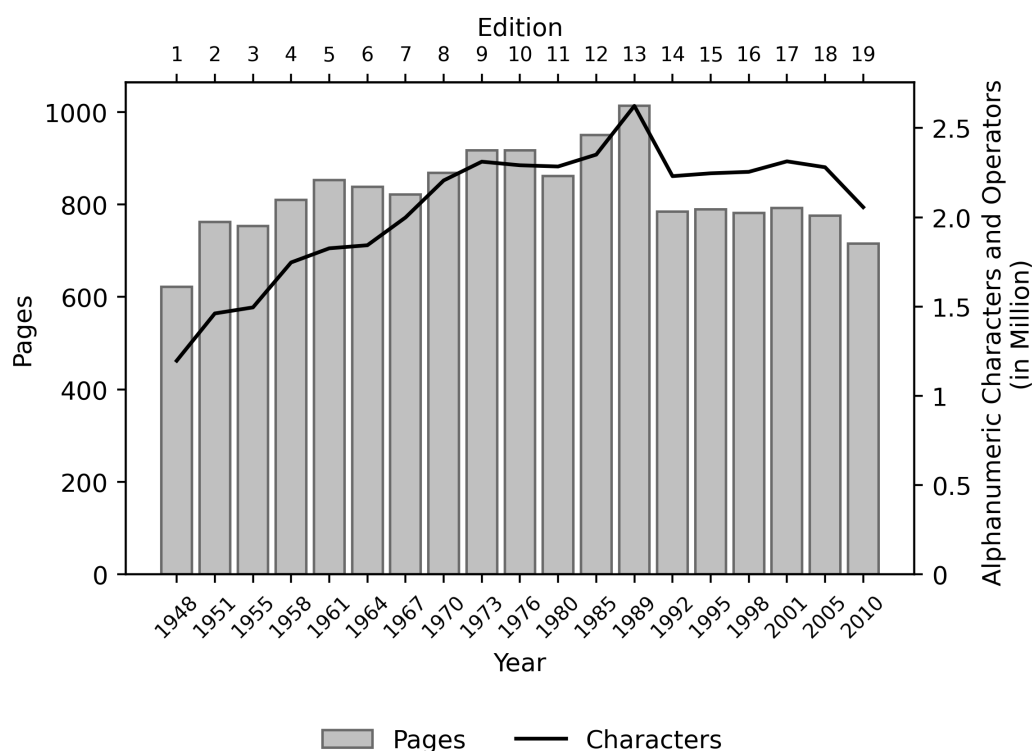
Concerning *Economics*, as shown, Bowles and Carlin (2020) account for only two editions. We think it is worth looking at all the textbook's 19 editions to exploit the complete set of the information offered by the time series. This will enable us to get a more granular understanding of how the canon of *mainstream economics* evolved over time and whether the patterns of this evolution fit into the overall story identified by Bowles and Carlin (2020).

3. The 19 Editions of *Economics*: A Story of Success and Change

3.1 Titles, Contributors, and Editions

In the preface of the 14th edition from 1992, Samuelson shares the textbook's historical origin. After Samuelson had joined MIT in 1940, the department head urged him to write a new introductory economics textbook in 1945. It took Samuelson three years to comply with this request. Finally, in 1948, the 1st edition of Samuelson's textbook entered the market and started to revolutionize economic teaching. Whereas its name was *Economics: An introductory analysis* initially, the title was later shortened to *Economics*. Moreover, Samuelson created the 10th edition of 1976 in collaboration with MIT economic historian Peter Temin, who focused on the empirics. Subsequently, William Nordhaus joined Samuelson and co-authored *Economics*, starting with the 12th edition of 1985. While Temin contributed to one edition, the collaboration with Nordhaus lasted over eight editions until Samuelson passed away in 2009, and the 19th edition was published one year later in 2010.

Figure 2 gives an overview of the textbook's size development measured by page and total character counts. The figure illustrates a steady increase in size between the 1th (1948) and the 13th (1989) edition. In this period, the textbook grew from about 600 to 1,000 pages, corresponding to an increase in character count of approximately one million. After that, starting with the 14th edition published in 1992, *Economics* contained circa 800 pages, consisting of 2 million characters. The size patterns remain constant until the last edition of 2010, for which Figure 2 indicates a further decrease in page and character counts.



Note: This table illustrates the size development of *Economics* between 1948 and 2010. Whereas the left y-axis indicates the number of pages per edition, the right y-axis represents the number of alphanumeric characters, punctuation marks, and the operators '<', '>', and '='. The lower x-axis shows the publication years of the editions. The upper x-axis exhibits the editions.

Figure 2: Differences in the Scope of *Economics* over Time

3.2 Major Structural Changes

The textbook's internal structure did not change substantially within the first eleven editions until Nordhaus became a formal co-author. The 1st edition consists of three major parts: the first covers *Basic Economic Concepts and National Income*, the second *Determination of National Income and its Fluctuations*, and the third *The Composition and Pricing of National Output*. Even though the structure is relatively consistent over time during the first editions,

it was novel compared to other textbooks. Accordingly, Elzinga (1992) regards starting the book with the analysis of national income, which would later be called *Macroeconomics*, as one of Samuelson's main innovations.

Samuelson implemented a minor change to the textbook's structure with the 9th edition by adding a new chapter. Labeled as *Winds of Change: Evolution of Economic Doctrines*, Samuelson includes the chapter in Part *Current Economic Problems of Economics*. It deals with the *Rudiments of Marxian Economics*, which Giraud (2020) assumes to be one of Samuelson's responses to the *radical economists'* harsh critiques.

The textbook's structure experienced more substantial changes when Nordhaus joined as co-author in 1985. The terms "macroeconomics" and "microeconomics" appeared in the titles of the book's parts. Additionally, a part named *Wages, Rents and Profits: The Distribution of Income* complemented the part on *Microeconomics: Supply, Demand and Product Markets*. Furthermore, the authors revised the content of the Part *Macroeconomics: Fluctuations of Output and Prices*. In particular, they added new sections and chapters focusing on unemployment and inflation. Likewise, the scope of the part *Macroeconomics: Money, Interest, and Deficits* was extended so that it not only deals with the supply and demand of money and fiscal policy but also with monetarism and rational expectations. A further novelty was the introduction of the model of aggregate demand and supply (AS-AD model) as an explanation for unemployment, inflation, and business cycles. Samuelson and Nordhaus (1985, p.viii) consider this adjustment to have far-reaching implications: "We have introduced aggregate supply and demand (AS-AD) as the central approach to understanding overall movements in prices and national output. All major issues in macroeconomics are now analyzed using these new tools". Modifications also characterize the structure of the 13th edition of 1989. The authors restructured the two parts covering macroeconomic topics. Accordingly, while the first part presented *Fundamental Concepts of Macroeconomics*, the second part dealt with *Macroeconomic Policy*.

A complete restructuring of the textbook occurred between the 13th and 14th editions. Among the eleven "major changes", Samuelson and Nordhaus (1992, pp.xv) view the "micro first" principle to be the most important one. According to this, *Economics* first discusses microeconomic topics before it shifts to macroeconomic issues. Moreover, the size reduction discussed above results from discarding sections that were no longer central to modern economics at that time. Also, in light of the collapse of socialist systems in the early 1990s, the name of the chapter *The Winds of Change: Alternative Economic Systems* changed to *The Winds of Change: The Triumph of the Market*.¹

¹Note that the authors eliminated this chapter, including its reminiscences of Marxist thoughts, with the 15th edition of 1995. The discussion of alternative economic doctrines was transferred to the macroeconomic part in a chapter named *The Warring Schools of Macroeconomics*, which compares Classical, Keynesian, Monetarist, New Classical, and 'Ultra-classical' (supply-side economics) approaches.

The most significant changes in the parts covering macroeconomic issues happened between 1992 (14th edition) and 2001 (17th edition). First, the authors removed the part on international economics and the global economy, traditionally located at the textbook's end. Second, some of the chapters from this part were assigned to other parts: The chapters on trade and trade policy were integrated into the part on applied microeconomics. The part *Economic Growth and Macroeconomic Policy* now also contained a chapter on *Exchange Rates and the International Financial System*. Thirdly, this split-up and re-arrangement enabled the inclusion of a new part dealing with *Unemployment, Inflation, and Economic Policy*, without causing an increase in the textbook's overall size. However, in the last edition of 2010, Samuelson and Nordhaus re-structured this part again by introducing a chapter on the *Frontiers of Macroeconomics*.

As a result, the textbook's structure has appeared very balanced since 2001: the introductory part on *Basic Concepts* is followed by six parts, equally split between micro- and macroeconomic topics. Moreover, the last parts of these two subfields (i.e., parts 4 and 7) have a clear focus on economic policy.

4. A Quantitative Assessment of the 19 editions of *Economics*

4.1 Data

In this section we investigate whether and to what extent the quantitative analyses confirm qualitative assessments concerning major shifts and subtle changes in the content of *Economics*. To apply quantitative textual analysis methods, we construct a dataset based on the 19 editions of *Economics*. At the beginning of the data generation process, the textbooks' hard copies are scanned. Subsequently, a trained Optical Character Recognition Software (OCR) translates the scans' content into a machine-readable format. Based on the evaluation of predicted characters from the testing data, the error rate is about 0.5 percent. Moreover, the errors are assumed to be random, implying the absence of a systematic bias. Thus, the textbooks' digitized contents enable accurate statistical analyses.

4.2 Method and Tools

We perform three different types of quantitative approaches to capture the dynamics within *Mainstream Economics* à la Samuelson and Nordhaus: (pooled) word count exercises, topic modeling, and sentiment analyses.

First, we aim at quantifying the coverage of i) individual economic concepts and scholars, and ii) entire economic schools of thought in *Economics*. To do so, we first count the number of occurrences of pre-specified key expressions per edition. Key expressions can refer to the names of scholars and economic concepts. Economic concepts can be represented by either single characters (e.g., mathematical operators), individual words (e.g., 'MPC'), or sequences

of words (e.g., 'general theory'). We further manually (and therefore subjectively) assign each key expression to a specific school of economic thought. This mapping allows us to calculate a coverage score for school of thought j in edition e , using the counts of its assigned key expressions ($i = 1, \dots, N$).

$$\text{Coverage Score } 1_{j,e} = \frac{\sum_{i \in I_j} \text{Key Expression Count}_{i,e}}{\text{Total Character Count}_e} * 100,000 \quad (1)$$

As illustrated in Equation 1, counts are normalized to 100,000 characters per edition to facilitate interpretability. Moreover, the approach accounts for the key expressions' exact representations as well as for potential variations. For instance, when determining how often the name 'Keynes' occurs, the count increases regardless of whether a sentence contains 'Keynes' or 'Keynesian'. Moreover, the algorithm is generally case-insensitive. Case-insensitivity allows for key expressions to be captured irrespectively from, for example, their position in a sentence. However, case-insensitivity is not applied when key expressions refer to names of scholars or proper names. Two reasons explain this exception. First, names are capitalized according to the grammar rules of the English language. Second, names of scholars might correspond to nouns included in the standard English vocabulary (i.e., Smith, Arrow). Thus, the application of case-insensitivity could potentially lead to false-positive increases in counts.

$$\text{Coverage Score } 2_{j,e} = \frac{\text{Coverage_Score_}1_{j,e}}{\max\{\text{Coverage_Score_}1_{j,1}, \dots, \text{Coverage score } 1_{j,19}\}} \quad (2)$$

To improve comparability of dynamics **between** schools, we perform a second normalization. Accordingly, we divide each of school j 's *Coverage Score 1* by school j 's maximum score over all editions, as illustrated by Equation 2. The resulting *Coverage Score 2* indicates the school j 's coverage at a given point relative to its maximum. It equals 1 for the edition with the highest coverage and is greater than or equal to 0 but less than 1 for the remaining editions.^{2,3}

Second, we identify individual topics discussed in Samuelson's *Economics* and measure their coverages over time relying on NLP techniques. To be precise, we use a Latent Dirichlet Allocation (LDA) topic model to evaluate the textbooks' content. This is valuable for our analysis as it allows to reduce of the

²Note that the comparability of dynamics between schools is limited: if schools A and B have an identical relative coverage as, for instance, stated by a *Coverage Score 2* of 0.5 in edition e , the conclusion that they are equally important is not necessarily correct. Compared to each school's previous and subsequent scores, the proper interpretation is that, for both, the coverage is half as high as in the edition where their coverage is the highest. On the other hand, if school A's and B's scores increased by the same degree between two editions, it can be concluded the change in their relative coverage is equally strong.

³When calculating coverage scores of individual expressions, we apply a similar logic as indicated by Equations 1 and 2.

degree of subjectivism associated with the word count approach. The reduction in subjectivism primarily results from the fact that the only required human interference in creating a topic model is specifying the number of topics to be extracted and tagging unsupervised machine learning outcomes. Additionally, as we use to a topic model created and provided by Bowles and Carlin (2020), we rule out even these two potential sources of bias. The following paragraphs describe the specification of Bowles and Carlin (2020)’s model, and explain the pre-processing of our data.

Bowles and Carlin (2020) specified their LDA model to extract 100 topics from an underlying corpus covering 27,436 research articles published in major economic journals between 1900 and 2014.⁴ The number of topics approximately matches the JEL codes count on the lowest hierarchical level. Each topic consists of 10,849 tokens and token weights. Tokens can either be individual words or bigrams that are sets of two adjacent words.⁵

We need to imitate the pre-processing procedure Bowles and Carlin (2020) applied to fit our data to their model. Therefore, we first manipulate our data by converting the text to lower case only. Subsequently, we performing tokenization and stemming operations. Stemming describes the process of stripping suffixes from words. It aims to avoid noise resulting from different manifestations of single word stems. The stemming algorithm applied is based on Porter (1980). During tokenization, strings (represented by an entire textbook’s content) are divided into substrings (words and bigrams, i.e., the tokens). After manipulating the data, each textbook’s content is evaluated, and a weight for each topic and edition is generated. Technically speaking, each topic’s contribution to the distribution of words is calculated for every edition of Samuelson’s *Economics*. Accordingly, 1900 weight-topic pairs exist.⁶

To enable an enhanced between-group comparison that takes into account normative assessments of the respective school of thought, we implement a third approach. This approach accounts for a pitfall associated with the previous methods: Even if a topic’s coverage in terms of quantitative relevance might be consistent over time, its connotation might change substantially. We use a further NLP tool to assess the key expressions’ connotations over time. Relying on IBM Watson’s standard sentiment custom model, a value ranging between -1 and 1 is calculated per key expression, school of thought, and edition. Whereas -1 indicates a strongly negative connotation, 1 represents a

⁴Covered journals include *Econometrica*, *Journal of Political Economy*, *The American Economic Review*, *The Economic Journal*, *Quarterly Journal of Economics*, *The Review of Economic Studies*, and *The Review of Economics and Statistics*.

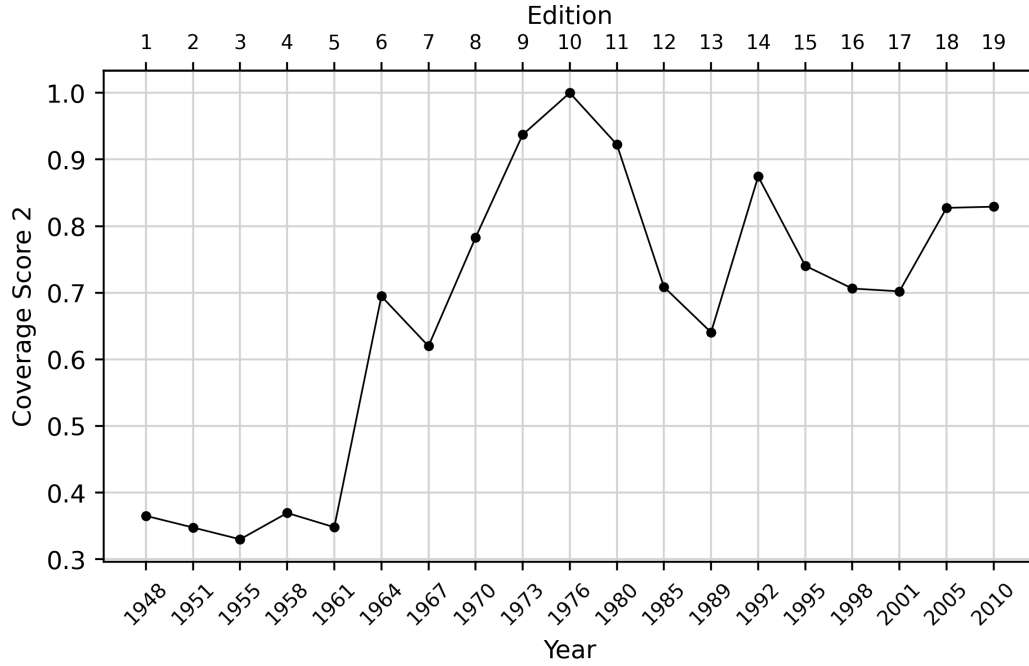
⁵As opposed to an approach followed by Ambrosino et al. (2018), Bowles and Carlin (2020)’s model does not subdivide the text corpus into multiple time windows to account for changes in the semantic content of topics. We expect topic-specific dictions to be relatively time-consistent given that all editions have been written by the same author(s). Thus, we assume a model relying on the entire text corpus to introduce less noise in our setup. The mathematical foundation to LDA models stems from Blei et al. (2003).

⁶Please note that LDA models treat texts as *bags of words* without accounting for the order of tokens.

sound positive sentiment.

4.3 Results

The quantitative textual analysis approach can help to measure the timing, the speed, the extent of, and the accompanying effects of major shifts in content and/or its assessment by the author(s). We start our investigation by looking at the formalization of *Mainstream Economics* since 1948.

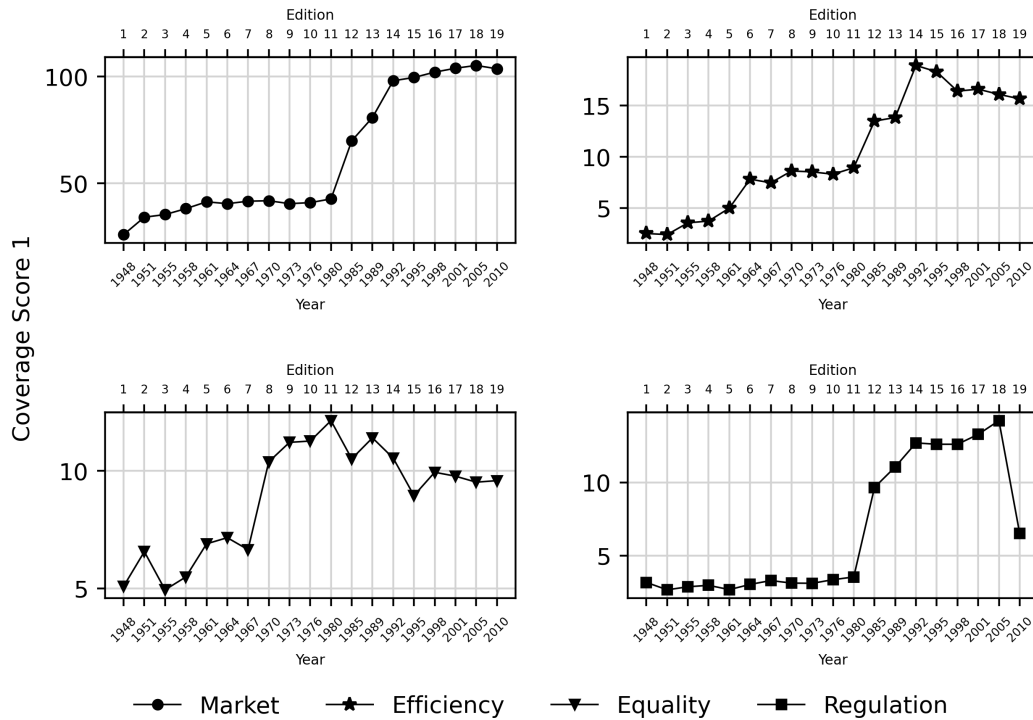


Note: This figure shows the development of the usage of mathematical operators in *Economics*. We normalize annual counts following Equation 2. Thus, the y-axis, which accordingly represents the *Coverage Score 2*, ranges up to 1.

Figure 3: Coverage of Mathematical Operators

For this specific analysis of the presentation mode, we perform a simple (group) count exercise of the most important formal operators (i.e., ‘=’, ‘>’ and ‘<’). In line with Equation 2, we normalize the findings to the edition with the maximum coverage, the 10th edition of 1976. As we can see in Figure 3, major increases in formalization took place between the 5th and the 6th (1961/64) editions as well as between the 7th and the 9th editions (1967/70). We also (and quite surprisingly) find a steady decline between the 10th and the 13th editions (1976/89). With the final editions the level of formalization in *Economics* grows again but stays well below the peak value of the mid-1970s. In summary, the formalization of economic reasoning increased substantially during the 1960s and has fluctuated around the level achieved since the early 1970s.

Next, we investigate the relative importances of certain key expressions over the 19 editions. We look particularly for the dynamics in the use of terms that are central for the understanding of modern economics, such as ‘market’, ‘efficiency’, ‘equality’, or ‘regulation’. As can be seen in Figure 4, we find that the use of ‘market’ has been steadily increasing over the whole period, mirroring the growing importance of market processes in *Mainstream Economics* since the 1940s. ‘equality’ and ‘efficiency’ – other traditional goals of economic policy – peak between the 11th and the 14th editions but lose importance afterwards. The most surprising finding concerns the use of the term ‘regulation’. One would expect the growing enthusiasm for market solutions to imply that the importance of the state as a regulatory agency diminishes in *Mainstream Economics*. However, our analysis reveals opposing patterns. First, low coverage is only visible during the time of Paul Samuelson’s single authorship at the beginning of the observation period. Next, the appearance of the new co-author leads to a steep increase in the use of state-related terms, including ‘regulation’. But, interestingly, the coverage of ‘regulation’ experiences a sudden decline with the last edition of 2010.

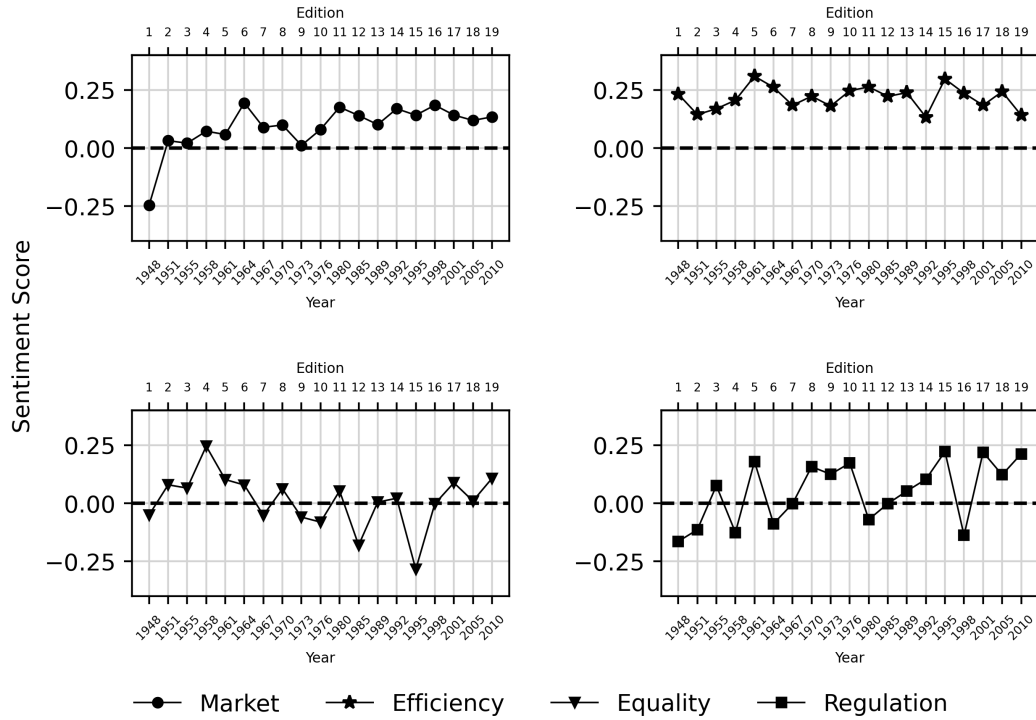


Note: This figure shows the development of the usage of the key expressions ‘Market’, ‘Efficiency’, ‘Equality’, and ‘Regulation’ in *Economics*. We normalize annual counts following Equation 1. Thus, the y-axis, which accordingly represents the *Coverage Score 1*, measures the key expression count per 100,000 characters for each edition. The underlying string matching algorithm is case-insensitive and thus accounts for multiple spelling varieties.

Figure 4: Coverages of Selected Key Expressions

The increase in the use of a specific term, however, can have two com-

pletely different reasons, which makes this interpretation difficult. It might either reflect the author's conviction that the term plays a much more important role in the understanding of contemporary economics, or it could indicate that the author(s) sees the need to criticize the respective term more intensively. One, therefore, has to know if the author regards the term in a rather positive or a rather negative sense. The results of our sentiment analyses can provide such information. As Figure 5 shows, the sentiment scores for 'efficiency' are constantly positive over time; the same holds true for the sentiment scores associated with the term 'market' since the 2nd edition of 1951. The sentiment scores for 'equality' exhibit, however, a negative trend between the 4th edition of 1958 and the 15th edition of 1995, with a reversal afterwards. Moreover, the scores for 'regulation' fluctuate strongly between positive and negative values.



Note: This figure exhibits sentiments associated with the key expressions 'Market', 'Efficiency', 'Equality', and 'Regulation' in *Economics*. We calculate the presented sentiment scores using IBM Watson's standard custom model. The y-axes represent the sentiment scores ranging between -1 (strongly negative connotation) and 1 (strongly positive connotation).

Figure 5: Sentiments of Selected Key Expressions

Our pooled word count analysis focuses on the relative importance of certain schools of economic thought within the various editions of *Economics*. We distinguish five different schools, to which we assign key expressions and names of academics. The schools include Classical Political Economy, Neoclassical Economics, Keynesian Economics, Marxist and Radical Economics, and

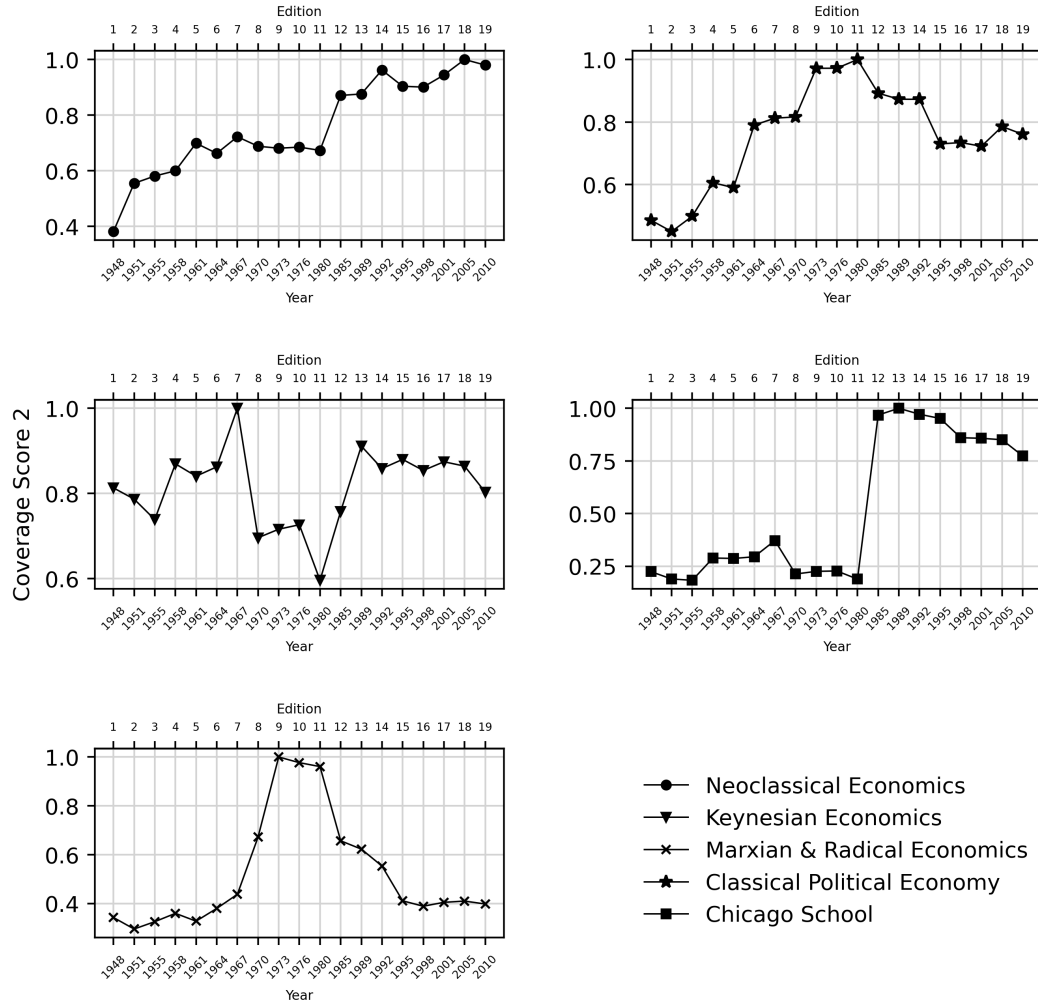
the Chicago School.⁷ The assignment is, of course, subjective. Nonetheless, it proves robust to minor corrections or changes. It should hence give a reasonable representation of the main schools of economic thought as illustrated in the family tree that Samuelson himself had presented in *Economics* (see Figure 1).

Figure 6 shows the dynamics in the coverage of the five schools over the 19 editions. The importance of Neoclassical Economics in terms of expression counts increases over the entire observation period. However, this increase is not steady: After stagnating between the 5th and the 11th editions, Neoclassical Economics experience a surge in coverage with the 12th edition, coinciding with Nordhaus becoming an author. A steady growth in coverage followed. Keynesian Economics show largely contrasting patterns until the 11th edition of 1980. However, starting with the 12th of 1985, Keynesian Economics experience a similar surge in coverage as Neoclassical Economics, reflecting the conjecture that *Mainstream Economics* à la Samuelson was based on a synthesis of neoclassical and Keynesian elements. Nonetheless, one can also see that the importance of Keynesian Economics begins to erode after the 13th edition. As to the evolution of the three other schools, it is evident that the importance of the Chicago School explodes with the 12th edition and the co-authorship of William Nordhaus. It remains on a very high level afterward, even if its coverage slightly reduces. Before their demise begins in 1985, Marxist and Radical Economics and Classical Political Economy peak between the 9th and 11th of 1973 and 1980. These findings may reflect the particular interest Samuelson had developed for both schools after being attacked by some radical economists in the late 1960s. But, at the same time, they might also highlight the lack of interest on Nordhaus's side.

Figure 7 illustrates the corresponding sentiment scores. It shows that the coverage of Classical Political Economy is somehow inversely related to its connotation, which is relatively high at the beginning and the end of the period of investigation. Moreover, Marxian and Radical Economics are valued quite negatively during most of the observation period; only in 1964 does one find a clear positive sentiment. Aside from this, according to the expectations, the sentiment associated with Neoclassical Economics is always positive. On the contrary, not in accordance with one's expectations might be the sentiment dynamics concerning Keynesian Economics. In particular, the negative sentiment of the 1st and 5th editions in combination with the other, predominantly neutral scores until the 13th edition of 1989 surprise. Finally, we find a complete reversal for the sentiment scores of the Chicago School with the 12th edition of 1985. Before 1985 the scores are negative or neutral. Since 1985, however, they are significantly positive.

We apply a second method to investigate the dynamics of covered topics. However, contrary to the previous exercises, the topic modeling approach rests on a model generated by Bowles and Carlin (2020) and thus is not influenced by

⁷In the appendix, we provide a list illustrating the selection and assignment of key expressions considered.

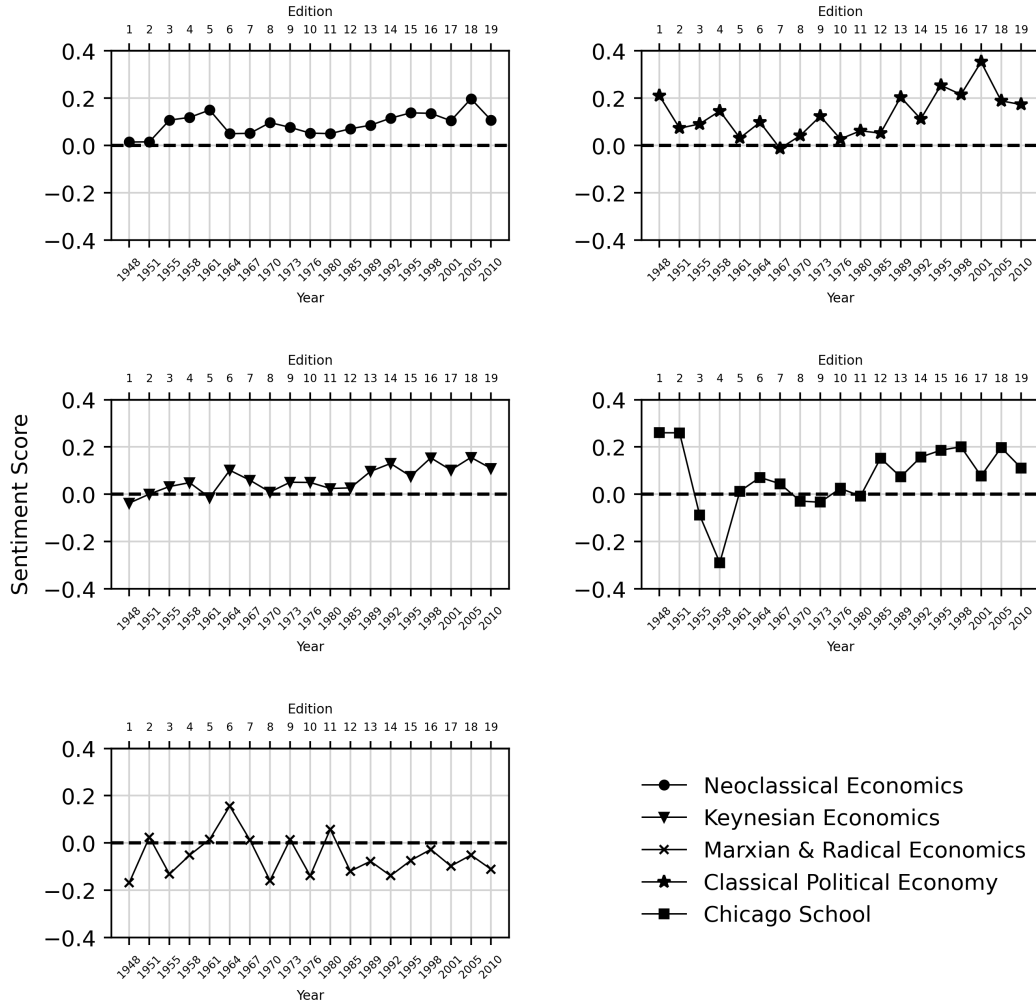


Note: This figure shows the development of the usage of selected key expressions associated with the following schools of economic thought in *Economics*: Neoclassical Economics, Keynesian Economics, Marxian and Radical Economics, Classical Political Economy, and Chicago School. We normalize annual counts following Equation 2. The y-axes accordingly indicate the *Coverage Score 2*, which ranges between 0 and 1. The value of 1 represents the maximum count of a time series. The underlying string matching algorithm is case-insensitive and thus accounts for multiple spelling varieties for key expressions other than proper nouns.

Figure 6: Coverages of Schools of Thought

any subjective assessment on our side. Moreover, as Bowles and Carlin (2020) created the topic model using unsupervised learning techniques, the overall degree of subjectivism is minimal. Rather than investigating developments of schools of thought, the second method focuses on 100 individual topics extracted from a large corpus of research articles. We pool 13 of the 100 topics into three broader categories for graphical analysis.

We first look at the dynamics of the topics containing explicit references to *Institutions*, as illustrated in the upper panel of Figure 8. According to Bowles and Carlin (2020), the labels of these are ‘US Federal Reserve, Insti-



Note: This figure illustrates sentiments associated with selected key expressions that we assigned to the following schools of economic thought: Neoclassical Economics, Keynesian Economics, Marxian and Radical Economics, Classical Political Economy, and Chicago School. We calculate the presented sentiment scores using IBM Watson's standard custom model. The y-axes represent the sentiment scores ranging between -1 (strongly negative connotation) and 1 (strongly positive connotation).

Figure 7: Sentiments of Schools of Thought

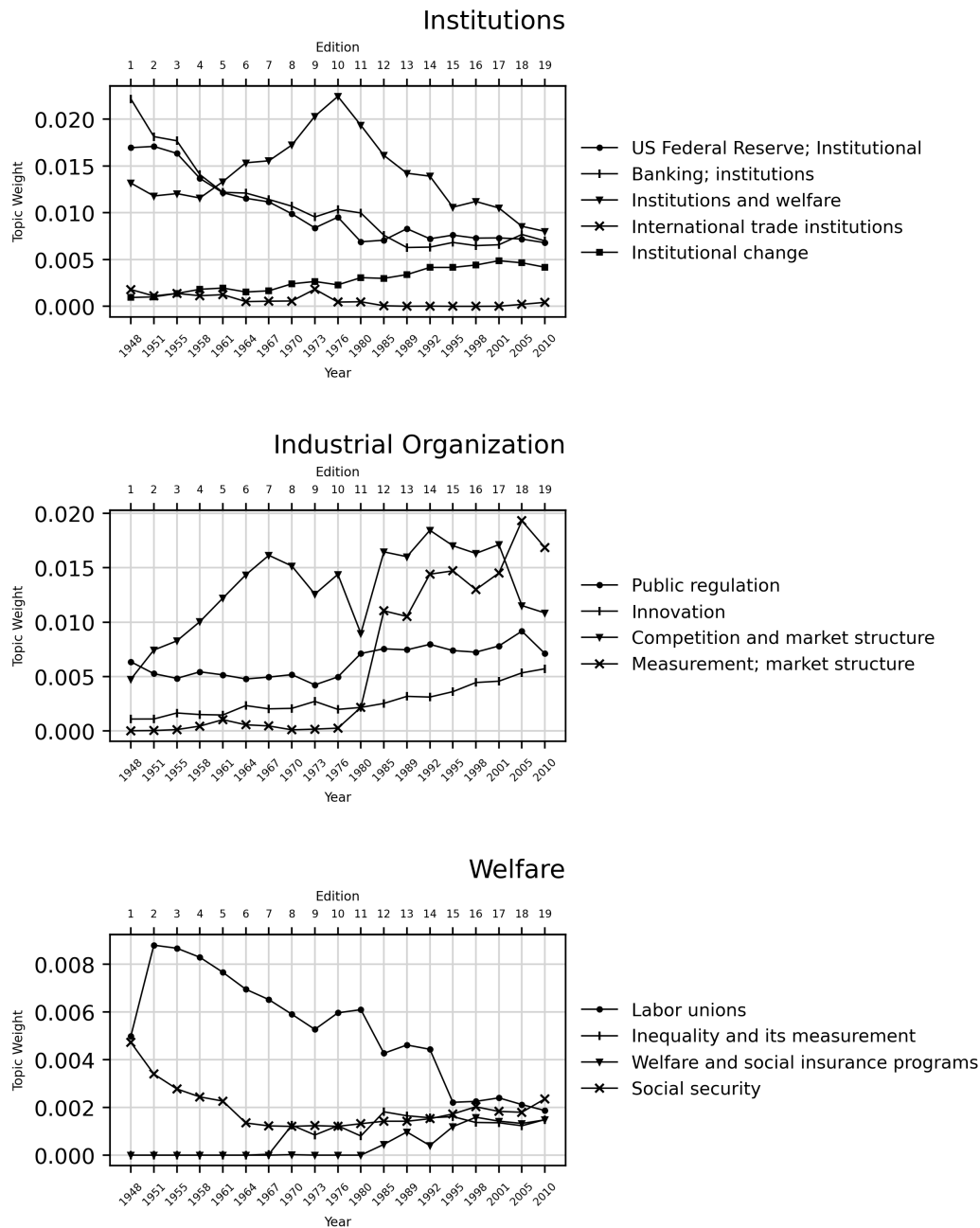
tutional', 'Banking; institutions', 'Institutions and welfare', and 'Institutional change'.⁸ What we find is an overall declining long-term trend in the weights of the selected topics. The topic 'Institutional change' is the only exception, showing a steadily increasing weight over time. Another notable characteristic is that the topic 'Institutions and welfare' peaks in importance in 1976. Ever since then, this topic's weight constantly decreases.

Second, we study dynamics of topics related to the concepts of markets and public regulation, summarized as *Industrial Organization*. The labels

⁸For a better graphical interpretability, the upper panel of Figure 8 does not include the topic 'Income tax; institutional' that exhibits a similar dynamic as 'Institutions and welfare'.

of the affected topics are ‘Public regulation’, ‘Innovation’, ‘Competition and market structure’, and ‘Measurement; market structure’. As indicated by the center panel of Figure 8, the weights of all topics increase over time. Whereas the weight increase is relatively smooth for the others, the topics ‘Competition and market structure’, and ‘Measurement; market structure’ rise sharply in importance with the 12th edition of 1985. Interestingly, despite the general increases in importance, as suggested, all but one topic experience declining weights between the 18th and 19th editions.

We summarize the third category for which we investigate dynamics as *Welfare*. This category includes the topics ‘Inequality’, ‘Welfare and social insurance programs’, ‘Social security’, and ‘Labor unions’. As a comparison of all panels’ y-axis scale illustrates, this category’s average weights are smaller than the other two’s. Interestingly, Samuelson did not account for the topics ‘Inequality’ and ‘Welfare and social insurance programs’ before 1970 (8th edition) and 1985 (12th edition), respectively. On the other hand, although playing a role already at the beginning of the observation period, especially the topic ‘Labor unions’ lost drastically in importance in the subsequent decades. This may even be the most important finding from the topic modeling analysis: one of the social institutions that had played a significant role in the canon of economics during the 1950s had lost much of its importance in a major economics textbook until 2000. This development is representative not only of the fading interest in the functioning of existing institutions but also of a shifting interest from *mainstream economics* towards markets and direct state interventions.



Note: This figure shows weights of topics identified by Bowles and Carlin (2020) over the 19 editions of *Economics*. The topic identification rests upon a large corpus of research articles and follows an unsupervised LDA topic modeling approach. Of the 100 topics Bowles and Carlin (2020) identify, we graphically illustrate 13 pooled into three categories. The upper panel corresponds to topics associated with *Institutions*, the center panel illustrates weight developments for topics corresponding to *Industrial Organization*, and topics in the lower panel relate to the category *Welfare*.

Figure 8: Weights of Topics Identified by Bowles and Carlin (2020)

5. Summary and Conclusion

Our study has applied methods of quantitative text and sentiment analysis to the 19 editions of Paul A. Samuelson’s textbook *Economics*, published between 1948 and 2010. This textbook, co-authored by William D. Nordhaus since 1985, stands out by its high penetration of the world market for introductory economics manuals. Our time series approach complements the quantitative cross-sectional analysis by Bowles and Carlin (2020) of various introductory economic textbooks. We can generally confirm findings by earlier qualitative research but have given them a quantifiable and thus more precise meaning. In detail, we outline four main findings.

First, we find that the formalization of economic reasoning rose dramatically during the 1960s and has fluctuated somewhat around the level achieved since the 1970s. Second, the use of the concepts of ‘market’ and ‘efficiency’ has steadily increased since the 1950s while maintaining a positive connotation. The sentiment score for ‘regulation’ has fluctuated between positive and negative values while the use of this concept grew slowly until the 1980s, and sharply increased afterwards. Thirdly, the topic modeling approach reveals that a more descriptive approach to existing institutions has been replaced by a more analytical treatment explaining institutional development in general. The topic ‘Competition and market structure’ has continuously expanded its relevance during the observation period, while the importance of the topic ‘Labor unions’ has drastically eroded since the early 1950s. Fourthly, concerning the schools of economic thought, it is only Neoclassical Economics that has increased its importance steadily with positive sentiment scores over the whole period. While the coverage of Keynesian Economics reached its maximum in the late 1960s, the Chicago School peaked in 1989. The highest positive sentiment score at all is found for Classical Political Economy in the 17th edition of 2001. Marxian and Radical Economics received the highest attention in the 1970s, but had very often negative sentiment scores.

When comparing our quantitative results to the findings in qualitative studies of Samuelson’s *Economics* we see the complementarity of both methods. Quantitative text analyses do not reverse our understanding of the major shifts in *mainstream economics* between 1948 and 2010, but, as stressed by Edwards et al. (p.287 2018), they “can help ‘statistizing’ and visualizing” developments in the canon. These developments include the increasing formalization of introductory economics in general, the rise of Neoclassical Economics and the permanently positive sentiment scores of Classical Political Economy, as well as the dynamics of various topical concepts.

We consider our study a further step in exploring the possibilities of quantitative text and sentiment analysis in the history of economic thought. The advantages and potential risks of these and related methods have been discussed in detail by Cherrier and Svorenčík (2018). Further research is certainly needed to study the changing importance of various schools of economic thought, relying on unsupervised topic modeling techniques instead of man-

ual assigned key expressions. Extended quantitative analysis would also be needed to clarify when, how, and to what extent changes in *mainstream economics* à la Samuelson and Nordhaus corresponded to shifts in public opinion represented by leading print or televised media. This might finally lead to a sound empirical testing of causal links between advances in economic theory, changes in *mainstream economics*, shifts in the public opinion, and major turns in economic policy strategies.

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Concepts and Representatives Associated with Schools of Economic Thought

Classical Political Economy

- **Concepts:** classical economics, classical political economy, classical school, absolute advantage, comparative advantage, Malthusian theory, division of labor, velocity of money, invisible hand, labor theory of value, Laissez faire, paradox of value, equation of exchange, Say's Law, real bills doctrine, law of reflux, economic man, homo economicus
- **Representatives:** Francis Hutcheson, David Hume, Adam Smith, Thomas Malthus, Francis Place, David Ricardo, Henry Thornton, John McCulloch, Jeremy Bentham, Johann von Thünen, John Stuart Mill, Thomas Tooke, Robert Torrens

Neoclassical Economics

- **Concepts:** neoclassical, allocative efficiency, Edgeworth box, average cost, average costs, marginal cost, marginal costs, variable cost, variable costs, budget constraint, budget line, consumption-possibility line, consumption possibility line, production-possibility frontier, production possibility frontier, perfect competition, imperfect competition, monopoly, duopoly, oligopoly, monopolistic competition, Cournot competition, competitive equilibrium, complements, substitutes, returns to scale, consumer surplus, producer surplus, consumption function, elasticity, elastic, inelastic, unit-elastic, deadweight loss, economies of scale, economies of scope, allocative efficiency, external economies, external diseconomies, externality, externalities, factor of production, factors of production, general equilibrium, tax incidence, tax burden, income effect, substitution effect, indifference curve, indifference map, inferior good, marginal-revenue-product, marginal revenue, MRP, marginal product, marginal-physical-product, marginal utility, MU, marginalism, Pareto efficiency, Pareto optimality, Pareto optimum, indifference price, ordinal utility
- **Representatives:** William Stanley Jevons, Francis Edgeworth, Alfred Marshall, Arthur Pigou, John Bates Clark, Irving Fisher, Knut Wicksell, Antoine Cournot, Léon Walras, Vilfredo Pareto, Kenneth Arrow, John Hicks

Keynesian Economics

- **Concepts:** Keynesian, General Theory, crowding out, aggregate demand, $C + I$, $C + I + G$, IS, LM, (including: IS', LM', IS'', LM'', etc.), multiplier [money multiplier], multiplier-model, CC, SS, 45° line, transaction demand, transactions demand, speculative demand, precautionary demand, precautionary motive, transaction motive, transactions motive, speculative motive, asset demand, deficit spending, disposable income, DI, dissaving, paradox of thrift, fallacy of composition, Phillips curve, M0, liquidity preference, marginal propensity to consume, marginal propensity to save, MPC, MPS, expenditure rounds, Solow–Swan model, Solow-model, Solow model
- **Representatives:** John Maynard Keynes, Richard Kahn, Joan Robinson, Alvin Hansen, Robert Solow, Paul Samuelson, Stanley Fischer

Chicago School (broadly defined, including monetarism and libertarians)

- **Concepts:** Chicago school, monetarism, monetarist, adaptive expectations, rational expectations, rational-expectations, new classical macroeconomics, Coase theorem, natural rate of unemployment, high-powered money, monetary base, velocity of money, equation of exchange, supply-side economics, Cagan-type, Cagan type, AS, AD (including: AS', AD', etc.) AS-AD, aggregate demand, aggregate supply, money multiplier, policy-ineffectiveness theorem, potential output, potential GNP, Lucas critique, Laffer curve
- **Representatives:** Frank Knight, Henry Simons, Friedrich A. Hayek, Jacob Viner, Milton Friedman, Anna Schwartz, Paul Volcker, Allan Meltzer, Karl Brunner, Beryl Sprinkel, Jerry Jordan, Leonall Andersen, Alan Walters, Ronald Coase, Thomas Sowell, George Stigler, Harry Markowitz, Merton Miller, Robert Lucas, Eugene Fama, Myron Scholes, Gary Becker, Edward C. Prescott, James Heckman, Robert Aliber, Phillip Cagan

Marxian and Radical Economics (including dissenters)

- **Concepts:** Marxian economics, Radical economics, Marxism, bourgeoisie, iron law of wages, labor theory of value, proletariat, surplus value, exploitation, reserve army, subsistence level, class struggle, capitalism, socialism, communism, race, racism, racial discrimination, wage discrimination, urban discrimination, sex discrimination, poverty, inequality, Blacks, New Left, Old Left, slum, ghetto, slavery

- **Representatives:** Karl Marx, Friedrich Engels, Eduard Bernstein, Richard D. Wolff, David Harvey, Kenneth Galbraith, John Gurley, John R. Coleman, Paul Sweezy

Personal Information of the Authors

Rainer Klump

- **Institutional Address:** Department of Economic Policy and Quantitative Methods, Goethe University Frankfurt, Theodor-W.-Adorno Platz 4, 60323 Frankfurt, Germany.
- **E-Mail:** klump@wiwi.uni-frankfurt.de

Marius Liebald

- **Institutional Address:** Department of Microeconomics & Management, Goethe University Frankfurt, Theodor-W.-Adorno Platz 4, 60323 Frankfurt, Germany.
- **E-Mail:** liebald@econ.uni-frankfurt.de

Ingo Sauer

- **Institutional Address:** Department of Economic Policy and Quantitative Methods, Goethe University Frankfurt, Theodor-W.-Adorno Platz 4, 60323 Frankfurt, Germany.
- **E-Mail:** isauer@wiwi.uni-frankfurt.de

Pascal Wolf

- **Institutional Address:** Department of Economic Policy and Quantitative Methods, Goethe University Frankfurt, Theodor-W.-Adorno Platz 4, 60323 Frankfurt, Germany.
- **E-Mail:** pascal.wolf15@gmail.com