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Graphs in Economics

Ibrahim Demir
University of South Carolina

Robert D. Tollison
Clemson University

Abstract

This study explores how economists present their ideas and findings in journal articles with a particular focus on the use of graphs. The study analyzes producing economics articles within a production theory framework and develops an economics article production function, in which graphs and words are inputs. Analyzing the articles published in American Economic Review between 1911 and 2010, the study finds that number of words, time, editors, number of chart displays, number of equation lines, presence of female authors, and female-only authorship are the significant determinants of the use of graphs. The study also finds that graphs and words complement each other.

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Contact: Ibrahim Demir - idemir@g.clemson.edu, Robert D. Tollison - rtollis@clemson.edu.
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1. Introduction

This study explores how economists present their ideas and findings in published journal articles by analyzing the articles published in *American Economic Review* between 1911 and 2010. The study explores the expected counts of graphs in written economics works through negative binomial estimations and finds that the size of papers, editorial preferences, number of chart displays, time, and author's gender are the significant determinants of the use of graphs.

Graphs have particular importance in economics studies. Many economics graphs constitute a theory by themselves and reveal the theory, issue, and significant aspects of the work at first sight. The Edgeworth Box, the IS-LM Curve, the Laffer Curve, the Kuznet's Curve, the Harberger Triangle, Samuelson's public expenditure graph, and Cheung's share-cropping graphs are among the examples of famous graphs that are remembered as both graphs and theories themselves [see Blaug and Lloyd (2010) for a list and presentations of famous graphs].

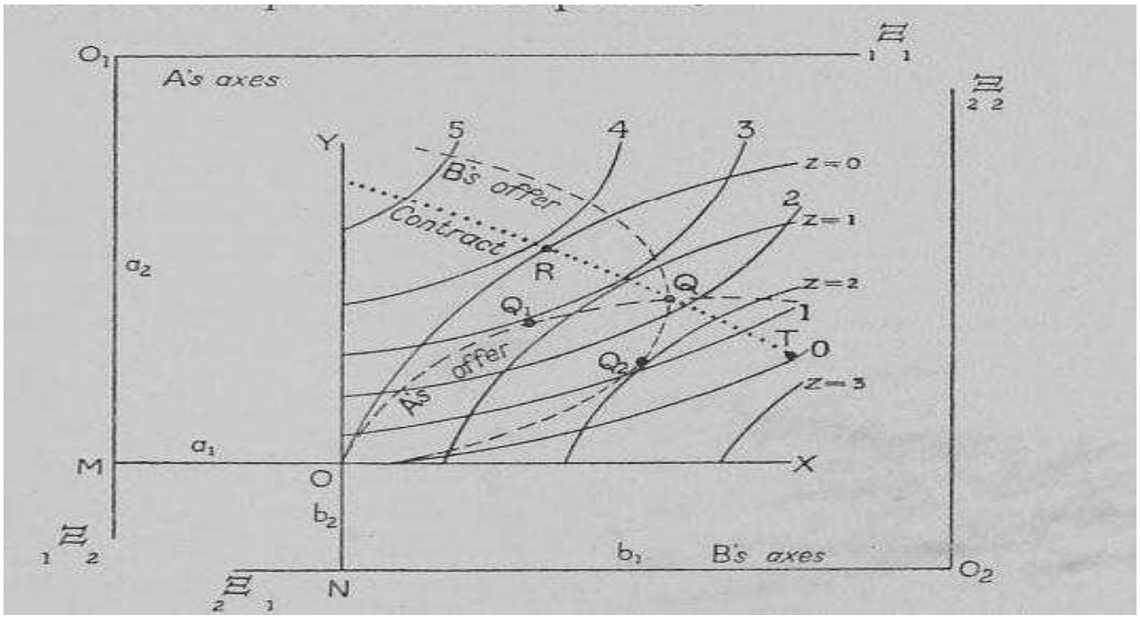
The anonymous saying of "a picture is worth a thousand words" best explains the efficiency of visual, depictive, and illustrative material in explaining, teaching, learning, and retaining information. Why and to what extent economists use graphs in presenting their works bear insights regarding the efficiency of graphs in complementing or substituting verbal expressions. Graphs can minimize the time and effort to explain, teach, learn, and retain a particular issue or theory in economics at a fixed cost of building human capital. Similar to the efficiency of pictures in telling a thousand words, the graphs that economists use are efficient in conveying and retaining the knowledge of economics for both the author and viewer. In this regard, the idea of the efficiency of graphs is similar to what Reksulak, *et al.* (2005) presented for the efficiency of languages. Letters and words in a verbal expression or text, lines and curves in a graph, algebraic expressions, and numbers are all models that simplify, represent, and explain what the human mind perceives, understands, and wants to reveal about changes, facts, and relationships between outcomes and thoughts. Thus, what makes economics as one of the strongest social sciences is its involvement of numeric, algebraic, and graphical ways of expression along with verbal statements in harmony to attain the maximum explanatory power.

It should be noted here that non-verbal tools may require human capital investment and treshold skills both on the author and the receiver side for a maximum explanatory power. Therefore, the contribution of non-verbal tools to the explanatory power of economics work may not be a linear one and vary with the amount of human capital both on the author and audience side.

Alternatively, graphs and algebraic statements, particularly, can be seen as signaling or decoration elements, rather than contributing factors to the explanatory power, that articles with graphs and equations and their authors are of higher quality. The school of thought, medium of publication, and editorial preferences also affect the decision to use and extent of use of graphs.

In addition to their contribution to the explanatory power regarding an economic issue, idea, or finding, economists' input demand for graphs can be viewed as barriers to entry as in medicine and law where the use of the language of Latin can be seen as barriers to entry along with licensing. With the exclusive use of Latin words and phrases, the incumbent members of the practice of law or medicine can communicate using a language that others cannot speak and understand at a reasonable cost. Similarly, along with relatively limited use of Latin, such as *ceteris paribus, nullum gratuitum prandium,* and *vice versa,* the use of graphs in economics can be viewed as the illustrative jargon of the profession that non-economists cannot fully understand and communicate at reasonable costs and enter the profession. The Edgeworth Box (Figure 1), which was originally presented by Edgeworth (1881) and later developed by Pareto (1906) and Bowley (1974:5), can be an example for this argument in a sense that, at first sight, a non-economist hardly can gather the workings of the bargaining process presented therein and draw conclusions from it.

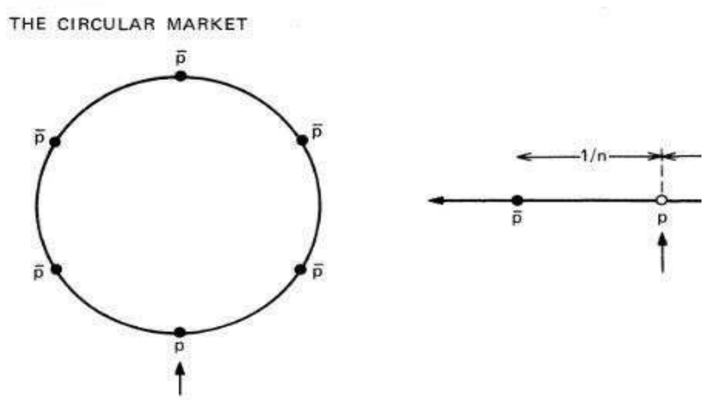
Figure 1. The Edgeworth Box



Source: Bowley, 1924:5.

Economists in our sample have used two types of graphs, theory graphs and data graphs, in their published articles. Theory graphs are the figures that depict the abstract functional relationships between variables whose quantities are represented on perpendicular axes as, mostly, two-dimensional geometric coordinate space. While they are consistent with the nature of the relationship that is to be explained between the variables, they do not necessarily result from actual data. The Edgeworth Box in Figure 1 is an example of theory graphs. As presented in Blaug and Lloyd (2010), theory graphs can go beyond figures that are depicted in geometric coordinate space. For instance, Salop's (1979) circular market model shown in Figure 2 is an example of a theory graph that is not presented in a perpendicular axes fashion.

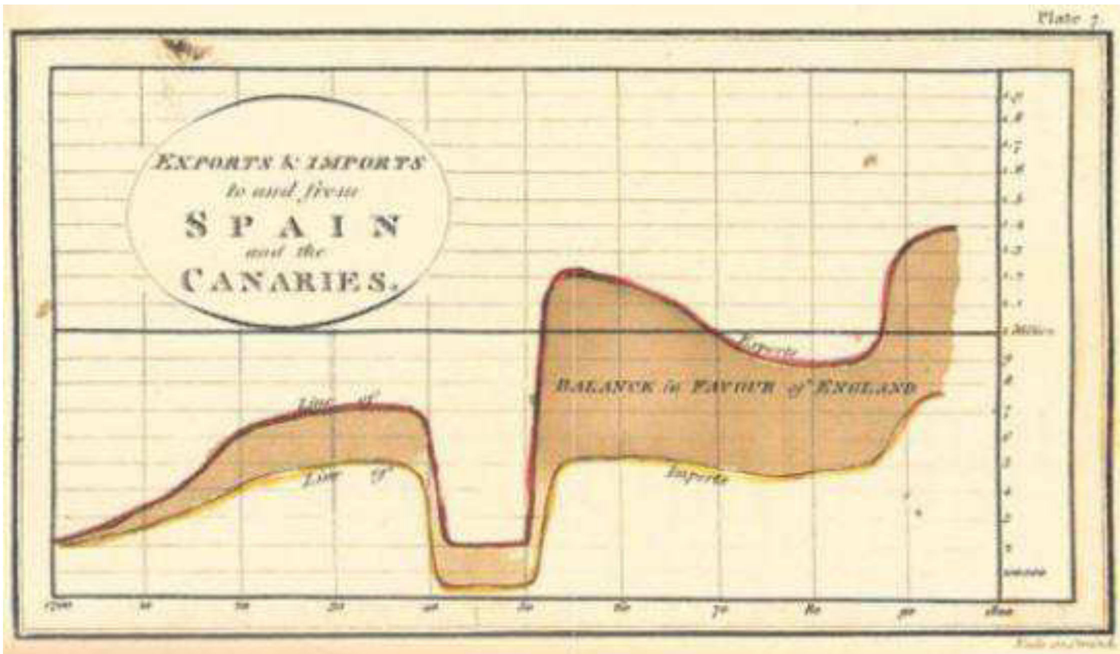
Figure 2. Salop's Circular Market Model



Source: Salop, 1979.

Data graphs, however, depict the relationships between variables based on the actual data. They are data plots in which each point represents an actual measurement or observation, such as the actual values of import and export over time. Playfair's (1786) import export graph in Figure 3 is an example of an early use of data graphs.

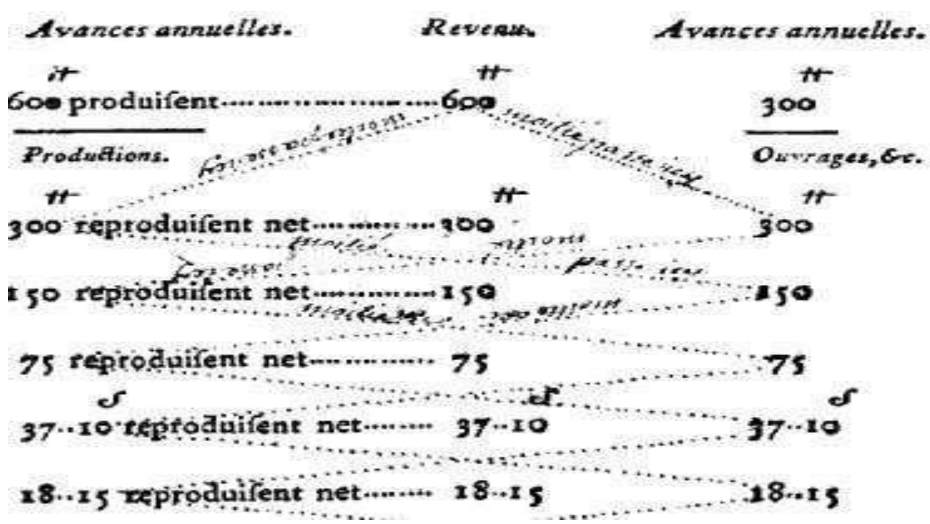
Figure 3. Playfair's Graphical Illustration of Actual Data



Source: Playfair, 1786.

Diagrammatic chart displays have been another non-verbal component of economics articles. They are used to illustrate the facts and interactions or relationships between variables that are shown in a non-graph (non-Cartesian) format. Quesnay's economic tables or circular flow model shown in Figure 4 is an example of chart displays.

Figure 4. Excerpt from Quesnay's Second Economic Table



Source: Quesnay, 1759.

Studies on the history and use of graphs, such as Maas and Morgan (2002), Humphrey (1992), and Blaug and Lloyd (2010), have discussed the discovery and early use of graphs and presented a collection of them. Yet, they have provided no empirical analysis on the use of graphs. This study, however, investigates the determinants of the use of graphs and explains the variations in their use by utilizing actual data that were obtained by quantifying the properties of articles published in *American Economic Review*.

The use of graphs in communicating what needs to be communicated must be analyzed separately for teaching, writing articles, writing books, recognition of the author, and learning and retaining the knowledge of economics, as the audience and purpose of these works are different. The primary focus of this current study is economics journal articles.

The study is laid out as follows. The next section explores the literature and history of the use of graphs in general scientific work and economics. Section 3develops an input demand model for graphs and words in an economics article within a Cobb-Douglass production function framework. Section 4 explains the data and data analysis. Potential improvements to the study are discussed in section 5. And, section 6 concludes.

2. Literature Review

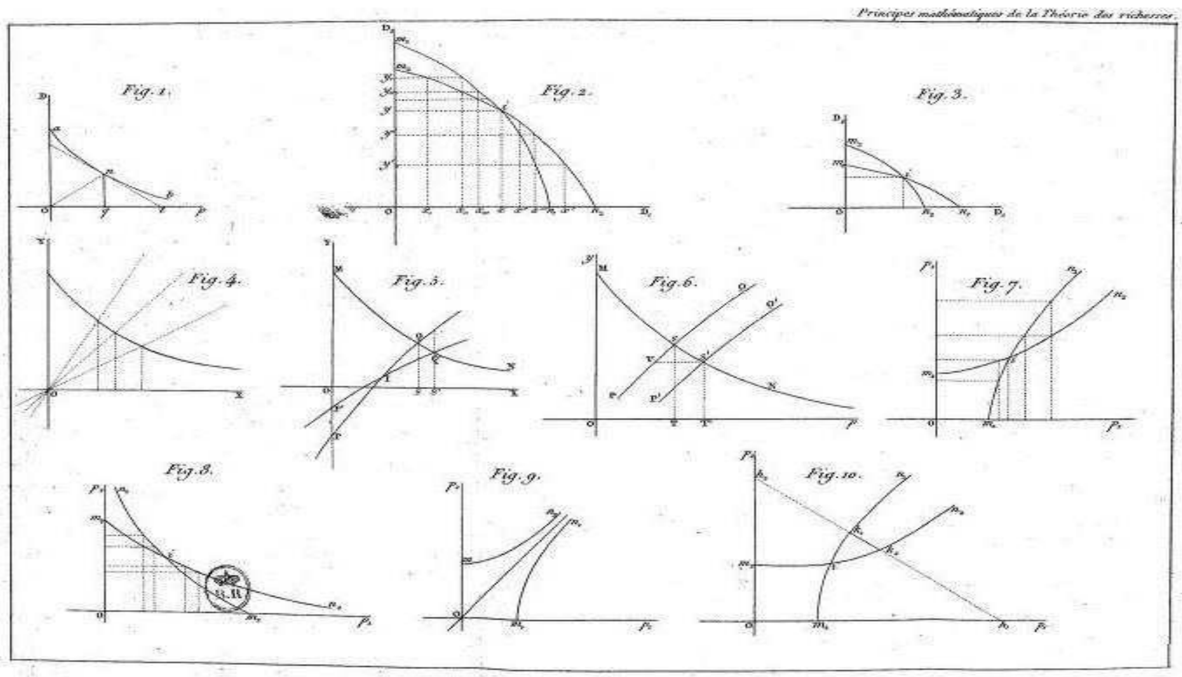
The idea of a graphical way of explanation in sciences arguably started with Oresme's (1353) work on qualities and motions (Part I, Chapters, i-xviii), in which he attempted to represent the measurements of speed, heat, pain, grace, and time on *latitudo* and *longitudo* as 'perpendicular lines' and 'sensible figures' as shown in Figure 5. Centuries later, Descartes introduced the Cartesian coordinate system with his *Discourse on Method* (Part 2, 1637), and, more importantly, in *Geometry* (1637).

Figure 5. An Excerpt from Oresme's Illustrative Work

Source: Oresme, 1353.

The visual display of actual economic data as charts, bar graphs, or similar illustrations arguably started with Playfair (1786) as Figure 3 shows an example of his data graphs. The theory graphs in economics works presumably started with Cournot (1838). According to Humphrey (1992), Cournot was the first to draw demand and supply curves for a good as shown in Figure 6.

Figure 6. Cournot's Supply and Demand Graphs



Source: Cournot, 1838 (at the end of the book).

Although the use of non-verbal (visual) methods of explanation in sciences started in the 14th century, their adoption in economics was arguably delayed. According to Maas and Morgan (2002), with Bowley (1901) and Jevons (1871) graphs became an own technique of explanation of the economic phenomena. They suggest that the reason for the relatively late adoption of graphs was the attitudes of the 19th century British economists toward history and statistics that statistical data (and graphs) would require 'repackaging' of historical events as *data* and they would fail to accommodate the complex and heterogeneous nature of the economic phenomena. This, perhaps, was the reason why Ricardo, Smith, and Mill explained the economic phenomena with introspection, reasoning, and deduction, but, with no graphs (see Morgan, 2002: 97-99 for a discussion). However, with the marginalist revolution and the importance of simplifying assumptions, such as, *ceteris paribus*, particularly, in economic analysis, this seemingly disadvantage of being unable to incorporate heterogeneous and complex nature of the reality or historical events, as suggested by Maas and Morgan (2002), became an advantage of graphs in showing the shifts and changes in the sets of relationships between economic variables and identifying the effects of changes in one variable on the outcome at a time in a two-dimensional geometric coordinate space. Therefore, the explosion in the use of graphs by economists after the late 1800's phase of the marginalist revolution should not be considered coincidental.

In an earlier study on the use of graphs in statistics and economics, Alfred Marshall (1885, p. 251), despite the 'dangers' of using graphs as scientific method, noted the advantage of graphs in 'enabling the eye to take in at once a long series of facts' and exploring the cause and effect relationships between historical events. Levasseur (1885) also explained the use of graphs as geometric procedures and their relation with statistics with examples of bar graphs, line graphs, and charts. Bowley (1901), as statistician and economist, allotted a whole chapter (Chapter VII) to provide detailed instructions on constructing graphs and explained the graphic method as a way of intelligibly showing large groups of figures in their entirety. While he considered graphs and diagrams auxiliary to averages (of numbers), he appreciated them as an "aid to the eye" and means of saving time (p.144).

Repeated survey studies done by Becker and Watts (1996) and Watts and Becker (2008) collected data on the techniques used in teaching economics. They found that graphs were viewed as "important" in statistics and econometrics, and "extremely important" in introductory (added in 2008) principles, intermediate-theory, and upper field division economics courses as a median response by the 625 economics instructors who participated in the study. On the contribution of graphs in student learning in economics, Cohn *et al.* (2001) found mixed results from the 1995 and 1997 runs of the study. While graphs lowered student learning in 1995, there was no significant difference between the contribution of lectures with and without graphs in 1997.

Zetland *et al.* (2010), also analyzed the effects of graphs in teaching and argued that modifications towards using a direct combination of algebra and graphs, such as, direct demand curve instead of an inverse demand curve that inverts the algebraic expression of demand as a function of price so that price is placed on the vertical axis, could reduce attrition of students due to confusion and increase comprehension. There have been several economists who are recognized and remembered by the graphs that they used in their works or whose works have been transformed into a graph later on. For instance, it was the graph of the Laffer Curve that made Laffer famous while the same phenomenon was first mentioned and explained by Khaldun in his Muqaddimah (1377: 230-232) and by Keynes (1933, p. 7) centuries later. Neither Khaldun nor Keynes had supported their explanations on tax revenue with a graph. The related story in Laffer's (2004) own words is as follows:

'The story of how the Laffer Curve got its name begins with a 1978 article by Jude Wanniski in The Public Interest entitled, 'Taxes, Revenues, and the 'Laffer Curve.' As recounted by Wanniski (associate editor of The Wall Street Journal at the time), in December 1974, he had dinner with me (then professor at the University of Chicago), Donald Rumsfeld (Chief of Staff to President Gerald Ford), and Dick Cheney (Rumsfeld's deputy and my former classmate at Yale) at the Two Continents Restaurant at the Washington Hotel in Washington, D.C. While discussing President Ford's "WIN" (Whip Inflation Now) proposal for tax increases, I supposedly grabbed my napkin and a pen and sketched a curve on the napkin illustrating the trade-off between tax rates and tax revenues. Wanniski named the trade-off "The Laffer Curve."

I personally do not remember the details of that evening, but Wanniski's version could well be true. I used the so-called Laffer Curve all the time in my classes and with anyone else who would listen to me to illustrate the trade-off between tax rates and tax revenues. My only question about Wanniski's version of the story is that the restaurant used cloth napkins and my mother had raised me not to desecrate nice things.

The Laffer Curve, by the way, was not invented by me. For example, Ibn Khaldun, a 14th century Muslim philosopher, wrote in his work The Muqaddimah: "It should be known that at the beginning of the dynasty, taxation yields a large revenue from small assessments. At the end of the dynasty, taxation yields a small revenue from large assessments."

A more recent version (of incredible clarity) was written by John Maynard Keynes'- footnotes and a subtitle were omitted-.

The story of the Laffer Curve is an example of how graphs can increase the efficiency of gaining reputation as an economist as well as the power of explanation of a phenomenon and explain the input demand for graphs. It seems it took a graph supposedly sketched on a restaurant napkin for Laffer to capture fame for the same phenomenon that Khaldun and Keynes mentioned and explained centuries and decades ago, respectively.

3. The Model

Writing an economics paper is a production activity. As the producer, an economist is rational with an objective to maximize the explanatory power, the output, by employing the least number of words and graphs (or other non-verbal elements) in a cost-minimizing fashion. In general, the choice over the amount of words and graphs, the input mix, of an economics article will be guided by the equi-marginal rule and elasticity of input substitution.

The production of an economics article can be specified as a two-input, for simplicity, production function as follows:

$$Q = F(G, W) \quad (1)$$

where Q is the output, measured in the size of articles, G is graphs, and W is words. This general form can specifically be written as a KRK production function (Kadiyala, 1972 and Meyer and Kadiyala, 1974) to present the multi-dimensional and reactional relationships between the use of various ranges of graphs and words in an article together as follows:

$$Q = F(G, W) = AF(G, W) = A(\omega_1 G^{2\rho} + \omega_2 G^{\rho_1} W^{\rho_2} + \omega_3 W^{2\rho})^{\frac{v}{2\rho}} \quad (2)$$

where, A is the efficiency parameter; ω_i is the share parameter ($i = 1,2,3$) with $\sum \omega_i = 1$; v is the returns to scale parameter, and ρ is a measure of the degree of substitutability of inputs. Note that ω_2 is the reaction parameter that accounts for the interactions between various amounts of graphs and words that are used in an article and (2) is homogenous of degree one when $v = 1$; $\rho_1 + \rho_2 = 2\rho$; and, $\frac{Q}{W} = F\left(\frac{G}{W}, 1\right)$.

Without imposing $\omega_2 = 0$ in (2), i.e., without reducing the specification to a standard CES one, it is hard to obtain explicit cost-minimizing conditions of use of graphs and words analytically. However, assuming $\rho_1 = \rho_2 = \rho$, the marginal rate of substitution (MRS) between graphs and words can be written as:

$$MRS = \frac{W(2G^{\rho} W^{-\rho} \omega_1 + \omega_2)}{G(\omega_2 + 2G^{-\rho} W^{\rho} \omega_3)} \quad (3)$$

Under the assumption of perfectly competitive input and output markets:

$$MRS = \frac{W(2G^{\rho} W^{-\rho} \omega_1 + \omega_2)}{G(\omega_2 + 2G^{-\rho} W^{\rho} \omega_3)} = \frac{r}{k} \quad (4)$$

where, r is the input price for graphs and k is input price for words.

Also, following Hicks (1932), under the assumption of constant returns to scale for (2), i.e., $v = 1$, the elasticity of substitution between graphs and words, σ, can be derived as follows:

$$\sigma = \frac{1}{1 - \rho + G^{\rho}\rho\left(-\frac{2\omega_1}{2G^{\rho}\omega_1 + W^{\rho}\omega_2} + \frac{1}{G^{\rho} + \frac{2W^{\rho}\omega_3}{\omega_2}}\right)} \quad (5)$$

In (5), note that the elasticity of substitution varies with the relative amounts of graphs and words and output elasticity of inputs. For instance, when articles have no graphs, $G = 0$, the elasticity of substitution is reduced to its minimum of $\frac{1}{1-\rho}$. Similarly, the minimum and maximum elasticity of input substitution between graphs and words are a function of $\frac{G}{W}$ and ρ (see Kadiyala, 1972, for additional scenarios of changes in elasticity of substitution based on changes in output elasticity of input and input use and for the expansion of the analysis into a k-input one).

4. Data and Data Analysis

The data for this study were collected from the articles published in the *American Economic Review (AER)*. There have been approximately 16,000 articles or items that have been published in *AER* between 1911 and 2010. After having removed papers and proceedings, reports, biographies, supplementary issues, comments, and replies, 5,176 articles remained as the population of articles (see Appendix I for a complete list of excluded articles and items). Each article was assigned an identification number and of 5,176 a random sample of 495 articles was drawn (approximately 10% of the population).

Based on 495 randomly selected *American Economic Review* articles, a typical economics paper mainly consists of words, equation lines, tables, data graphs, theory graphs, and chart displays as shown in Table I:

Table I. Components of an Economics Article (n = 495)

Component	Mean Size Share (% square inch)
Words	71.5%
Equations	16.0%
Tables	6.3%
Data Graphs	2.9%
Theory Graphs	1.1%
Chart Displays	0.5%

Table I shows the main components of an economics article after corrections for blank areas using the summary statistics of quantifications of articles reported in Appendix II. On average, economists mostly used words in their written journal work with a share of 71.5% of the total area of articles. The second largest component is equation lines with a 16% of share. Tables have 6.3%, data graphs have 2.9%, theory graphs have 1.1%, and chart displays have a 0.5% share. The combined size-share of data graphs and theory graphs is 4%. For the count-use of graphs, economists used .83 count theory graphs and 1.41 counts of data graphs per article on average. The combined use of graphs is 2.24 counts per article on average. Theory and data graphs were pooled under the variable name "number of graphs" in the estimations.

The AER articles were downloaded from the JSTOR website in PDF format. Articles were converted into MS Word format to count the number of words, measure the sizes of graphs, data graphs, tables, and chart displays by using the built-in vertical and horizontal ruler. Word count of the articles was collected by utilizing the AnyCount software. Number of equation lines was standardized to single-column view. The properties of randomly selected articles have been quantified to construct the variables: volume, number, year, JEL classifications (only for 113 articles within the sample), number of JEL classifications, number of pages, number of authors, number of female authors, if there is a female author, starting page, number of words, size of graphs, number of graphs, size of data graphs, number of data graphs, size of tables, number of tables, size of chart displays, number of chart displays, and equation lines.

Articles before and after 1970 differ in their area size per page, number of words per square inch, and single-double column-view properties. Therefore, the mean use area per page was corrected as 39.76 square inches and the number of words per square inch was found as 16.3 after sampled measurements.

The data on graphs present a zero-inflated distribution. That is, 59% of articles in the sample do not contain graphs at all. There can be two explanations for why some authors did not use a graph: i) they were "certain" about words or other expression ways to present their ideas or they simply are against the graphs and they "strategically" avoid them, ii) they just did not use graphs incidentally because of some underlying reasons or by chance. Therefore, following Mullahy (1986), Heilbron (1989), and Lambert (1992), Zero-Inflated Poisson (ZIP) and Zero-Inflated Negative Binomial (ZINB) models are preferred to OLS estimation. Having the dependent variables, number of graphs and size of graphs, zero-inflated and over-dispersed (variance = 23.70 > mean = 2.24, N=495), the following ZINB distribution was assumed for both number-count and size-count estimations (also see the histograms in Appendix V):

$$Pr(GRAPHS_i = g_i) \; = \begin{cases} \omega_i + (1-\omega_i)\left(\frac{1}{1-\alpha\lambda_i}\right)^{\frac{1}{\alpha}} & for\ g_i = 0; i = 1,2, \dots \dots n \\ (1-\omega_i)(\frac{\Gamma\left(\frac{1}{\alpha}+g_i\right)}{\Gamma\left(\frac{1}{\alpha}\right)(g_i!)}(\frac{\alpha\lambda_i}{1+\alpha\lambda_i})^{g_i}(\frac{1}{1+\alpha\lambda_i})^{\frac{1}{\alpha}} & for\ g_i > 0; i = 1, 2, \dots \dots . n \end{cases} \quad (6)$$

where, Pr , is the probability of graphs in an article, ω_i is the probability of excess zeros and is assumed to follow a logit distribution, such that, $logit(\omega_i) = X_i\beta$ where X_i is a $1xk$ vector of covariates and β is a $kx1$ column vector of coefficients. λ_i is the mean of the underlying negative binomial distribution, α is the dispersion parameter, such that, $\alpha \to 0$ would mean the ZINB model collapses into a ZIP (Zero-Inflated Poisson) model. The mean of the distribution in (13) is $E(GRAPHS_i) = (1-\omega_i)\lambda_i$ and the variance is $var(GRAPHS_i) = (1-\omega_i)\lambda_i + (1+\omega_i\lambda_i + \alpha\lambda_i)$. Based on these specifications, number-count and size-count model estimations of graphs have been conducted.

4.1.Number-Count ZINB Estimation

Table II. Number-Count ZINB Estimation Results (Dependent Variable: total number of graphs)

COUNT	Estimation 1	Estimation 2	Estimation 3	Estimation 4
Number of Words	0.000146***	0.000145***	0.000150***	0.000148***
	(7.36)	(7.31)	(7.54)	(7.46)
Number of Chart Displays	-0.234**	-0.234**	-0.241**	-0.239**
	(-2.84)	(-2.84)	(-2.90)	(-2.90)
Constant	-0.0368	-0.024	-0.0658	-0.0403
	(-0.17)	(-0.11)	(-0.30)	(-0.19)
INFLATE				
Female only author	1.515*		1.451*	
	(2.5)		(2.5)	
If there is a female author		1.472*		1.355*
		(2.5)		(2.49)
Year	-0.0616***	-0.0620***		
	(-5.11)	(-5.05)		
Editor 2			-1.638*	-1.636*
			(-2.01)	(-2.02)
Editor 3			-3.037***	-3.022***
			(-3.53)	(-3.54)
Editor 4			-3.396***	-3.373***
			(-3.75)	(-3.77)
Editor 5			-3.285***	-3.257***
			(-4.28)	(-4.30)
Editor 6			-3.874***	-3.813***
			(-3.33)	(-3.44)
Editor 7			-4.226***	-4.154***
			(-5.12)	(-5.26)
Editor 8			-4.145***	-4.203***
			(-4.62)	(-4.62)
Editor 9			-6.052***	-5.817***
			(-3.97)	(-4.45)
Constant	121.0***	121.7***	2.686***	2.702***
	(5.16)	(5.09)	(4.39)	(4.43)
Lnalpha	0.30	0.312	0.302	0.273
	(1.31)	(1.38)	(1.39)	(1.26)
n	495	495	495	495
Likelihood-ratio test of alpha=0: chibar2(01) =	489.3	488.25	488.27	488.09
Pr>=chibar2 =	0.000	0.000	0.000	0.000
Vuong test of zinb vs. standard negative binomial: z =	6.10	6.10	6.15	6.13
Pr>z =	0.000	0.000	0.000	0.000

t-statistics in parentheses; * p<0.05, **p<0.01, *** p<0.001.

Table II shows the number-count ZINB estimation results based on distribution in (6). All of the estimated models shown in columns 1, 2, 3, and 4 of Table II are significant based on the Likelihood Ratio Chi-Square tests. Based on LR test on the over-dispersion parameter alpha and Vuong test for ZINB vs. ZIP (Zero-inflated Poisson) listed on the bottom section of Table 2, the ZINB model was chosen against the negative binomial and ZIP models for all estimations.

In the Estimation 1 column of Table II, significant coefficients are the number of words and number of chart displays for the count part, and having only female author and year for the inflated part of the model. For each unit increase in the number of words, the expected number of graphs would increase by a factor of 1.00 [=exp(0.000146)], *ceteris paribus*. A one-unit increase in the number of chart displays would cause the expected number of graphs to decrease by a factor of .79, *ceteris paribus*.

For "certain" or "strategic" zeros (the inflate part of the model), having a female only author would increase the odds that an article will be a certain zero-graph article by a factor of 4.54 [=exp(1.515)], relative to a mixed authorship article, *ceteris paribus*. That is, the articles with female only authors are more likely to be a certain or strategic-zero-graph one.

A one-year increase in time would decrease the odds that an article will be a certain or strategic zero article by a factor of .94 [=exp(-.0616)], *ceteris paribus*. That is, time would diminish the odds of an article being a strategic zero-graph article, indicating that over time articles strategically have had more graphs.

In the Estimation 2 column of Table-2, the only difference is the replacement of the variable female only author with the variable if there is a female author. Not to repeat the interpretation of the same variables, the availability of a female author increased the odds that an article will be a certain or strategic zero article by a factor of 4.36 [=exp(1.472)], *ceteris paribus*.

Estimation 3 replaces the year variable with editors because of multi-collinearity concerns. In this estimation, an increase in the number of words would increase the expected number of graphs by a factor of 1, approximately. An increase in the number of chart displays, however, would decrease the expected number of graphs by a factor of .79, *ceteris paribus,* indicating a trade-off and substitution effect between graphs and chart displays. For the excess zero part of the model, having a female only authorship would increase the odds that an article would be a certain or strategic zero-graph article by a factor of 4.26, *ceteris paribus*. Editors relative to the first editor of the AER, Davis R. Dewey (1911-1940), who served the longest term, would significantly reduce the odds that articles would be certain or strategic zero articles with the largest difference of the 2nd editor, Paul T. Homan (1941-1951), and smallest difference of the 9th editor, Robert A. Moffitt (2004-2010). The odds that the articles that were written during the editorship of the 2nd and 9th editor would be certain or strategic zero articles are significantly lower than that of the first editor by a factor of 0.19 and .002, respectively, *ceteris paribus*. The majority of the editors significantly reduced the odds that articles would be a certain-zero-graph one by a factor of .02, indicating both editorial and time effects that over time articles strategically have had less zero-graphs.

Estimation 4 in Table II also reports similar results except for the replacement of the variable of female-only authorship with having a female author. Having a female author increased the odds that an article would be a strategic or certain zero-graph article by a factor of 3.88, *ceteris paribus*.

4.2. Size-Count ZINB Estimation

Estimations based on number of graphs treat all graphs in articles the same size-wise and do not shed light on the spatial allocation of pages of articles by authors. Graph size in articles greatly varies in our sample (standard deviation of graph size is 66.44 square inch). Therefore, analyzing the square-inch utilization of each page and size-allocation of different components in each article matters. The histogram of size of graphs in Appendix V shows that the size-counts of graphs in articles displays the characteristics of a Poisson distribution similar to the one with the number-count model. Also, having variance greater than the mean (4414.04>21.90, N=495) indicates over-dispersion of the size of graphs. Thus, similar to the number-count model, a ZINB estimation has been utilized for the size-count properties of the data. Table III shows the ZINB estimation results of size-count model:

Table III: Size-Count ZINB Estimation Results (Dependent Variable: Graph Size, square inch)

COUNT	Estimation 1	Estimation 2	Estimation 3	Estimation 4
Words size (sqr.in)	0.002***	0.002***	0.002***	0.002***
	(7.34)	(7.34)	(7.34)	(7.34)
Equation line size (sqr. in)	-0.001**	-0.001**	-0.001**	-0.001**
	(-2.70)	(-2.71)	(-2.71)	(-2.71)
2 Authors	0.284*	0.284*	0.286*	0.286*
	(2.03)	(2.04)	(2.05)	(2.05)
3 Authors	-0.382	-0.38	-0.375	-0.374
	(-1.76)	(-1.75)	(-1.73)	(-1.73)
4 Authors	1.159	1.159	1.168	1.168
	(1.72)	(1.73)	(1.74)	(1.74)
5 Authors	-0.459	-0.459	-0.459	-0.459
	(-0.50)	(-0.50)	(-0.50)	(-0.50)
Constant	2.695***	2.696***	2.697***	2.697***
	(16.63)	(16.64)	(16.68)	(16.68)
INFLATE				
Female only authorship	0.815**		0.709*	
	(2.89)		(2.51)	
If there is a female author		0.839**		0.728**
		(3.04)		(2.61)
Year	-0.0408***	-0.0414***		
	(-8.31)	(-8.33)		
Editor 2			-2.019*	-2.019*
			(-2.32)	(-2.32)
Editor 3			-3.210***	-3.210***
			(-3.83)	(-3.83)
Editor 4			-3.221***	-3.221***
			(-3.89)	(-3.89)
Editor 5			-3.176***	-3.177***
			(-4.15)	(-4.15)
Editor 6			-3.492***	-3.493***
			(-4.16)	(-4.16)
Editor 7			-3.814***	-3.817***
			(-5.14)	(-5.15)
Editor 8			-4.093***	-4.125***
			(-4.99)	(-5.02)
Editor 9			-4.266***	-4.308***
			(-5.67)	(-5.71)
Constant	80.97***	82.24***	3.575***	3.574***
	(8.33)	(8.35)	(4.99)	(4.98)
Lnalpha				
_cons	-0.228*	-0.229*	-0.232*	-0.232*
	(-2.07)	(-2.08)	(-2.12)	(-2.13)
n	492	492	492	492
Likelihood-ratio test of alpha=0: chibar2(01) =	7799.34	7799.29	7799.07	7799.05
Pr>=chibar2 =	0.000	0.000	0.000	0.000
Vuong test of zinb vs. standard negative binomial: z =	6.07	6.14	6.56	6.59
Pr>z =	0.000	0.000	0.000	0.000

t-statistics in parentheses; * p<0.05, **p<0.01, *** p<0.001.

All of the estimations in Table III are significant as a whole based on Likelihood Ratio Chi-Square tests. ZINB specification is confirmed with Likelihood Ratio test on alpha = 0 and Vuong test for ZINB vs. standard negative binomial estimation as listed on the bottom of Table III.

In the Estimation 1 of Table III, a one-unit increase in the size of words would lead to an increase in the expected size of graphs by a factor of 1, *ceteris paribus*. That is, the larger the size of words the larger the size of graphs in an article. Equation line became significant in the count part of the estimations in contrast to the number-count estimations, where the number of chart displays was significant. A unit increase in the size of equation lines would decrease the expected size of graphs by a factor of .99, *ceteris paribus*. Having two authors relative to one author significantly increases the expected size of graphs by a factor of 1.32, *ceteris paribus* (having three and four authors, relative to single authorship, had only 10% significance level impact while having five authors was not significant at all).

In the inflate part of the Estimation 1 in Table III, having a female only authorship increased the odds that an article would be a certain zero-graph-size article by a factor of 2.26, *ceteris paribus*. A year increase in time would decrease the odds that an article would be a zero-graph-size article by a factor of .96, *ceteris paribus*.

Estimation 2 in Table III reports similar results in the count part with the only difference of the replacement of female only authorship with the existence of at least one female author. Having at least one female author relative to not having one increased the odds that an article would be a certain zero-graph-size article by a factor of 2.3, *ceteris paribus*.

Estimation 3 in Table III replaces year with editorial categorical variable in the inflate part of Estimations 1 and 2. While variables in the count part of the model had similar coefficients, the effect of having female only authorship went down with the inclusion of editorial categories in the inflate part. Having a female only authorship would increase the odds that an article would be a certain zero-graph-size article by a factor of 2.03, *ceteris paribus*. All of the editors significantly differed from the first editor in reducing the odds that an article would be a certain zero-graph-size article, indicating increase in the odds of articles with non-zero graph size over time.

Estimation 4 in Table III replaces female only authorship with having at least one female author in the inflate part of the Estimation 3 and shows that having a female author would increase the odds that an article will be a zero-graph-size article by a factor of 2.07, *ceteris paribus*. Editorial effects and other effects are similar to the ones in Estimation 3.

5. Discussion

In trial estimations, using robust and no-constant options lead to little or no change in results. We are aware that the potential endogeneity of words and word size in both number-count and size-count estimations is a concern. While the number and size of words could affect the number and size of graphs, the number and size of graphs could also affect the number and size of words. However, limited number of variables regarding the articles and, especially, the lack of information regarding the authors, such as, tenure, age, where they worked, and where they received their education or degrees, prevented us from conducting instrumental variable analyses and tests.

The significant time effect that we found is potentially reflecting the changes in technology and production costs. Significant editorial categories are also meaningful in terms author's adjustments to editorial constraints and expectations. However, the interpretation of the effects of significant female authorship is not that straightforward. Editorial attitudes, either positive or negative, towards female authors might have played a role in their strong choice over certain-zero-graph articles. For instance, a strong pro-graph editor might have accepted papers with no graphs from female authors as positive discrimination. However, the effects of female authorship and female authors' attitudes toward non-verbal ways of expressions require more empirical work.

The inclusion of the number and categories of JEL classification of articles would be a major improvement to the study. However, we had only 113 articles with JEL classifications in our sample. Inclusion of JEL classifications in trials reduced the number of observations and did not converge. Thus, we favored capturing the whole history of AER articles against analyzing more recent articles only with JEL classifications. Another improvement to the study could come with the inclusion of footnotes and list of references, and other journals in addition to AER. In the current analysis, footnotes and references went into the number and size of words. This separation, especially, the number of cited references, would be interesting to look into. We also leave the effects of using graphs on the popularity of economists to future studies.

6. Conclusion

This study analyzed how economists presented their ideas and findings in journal articles by quantifying the properties of randomly selected 495 articles that had been published in *American Economic Review* between 1911 and 2010. In the sample period, economists have used .81 count theory graphs and 1.41 count data plot graphs per article on average. They also have allocated 1.1% of the total square inch size of their articles for theory graphs and 2.9% for data graphs. Combined size share of graphs was 4% for both theory and data graphs. Through ZINB (Zero-Inflated Negative Binomial) estimations for both the number-count and size-count estimations, the number of words, size of words, number of chart displays, size of equation lines, having two authors relative to one had significant effects on the expected counts of graphs and graph sizes. Also, time (measured in years), having female only authors relative to mixed authorship, having a female author, and editorial categories had significant impacts on the odds that an article would be a certain zero-count graph or zero-graph-size article.

In both the number-count and size-count estimations, the study found strong complementarity between the use of graphs and words indicating that articles with more graphs had more to explain in words. This finding deserves further investigation in terms of the efficiency of graphs or substitutability of words with graphs.

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