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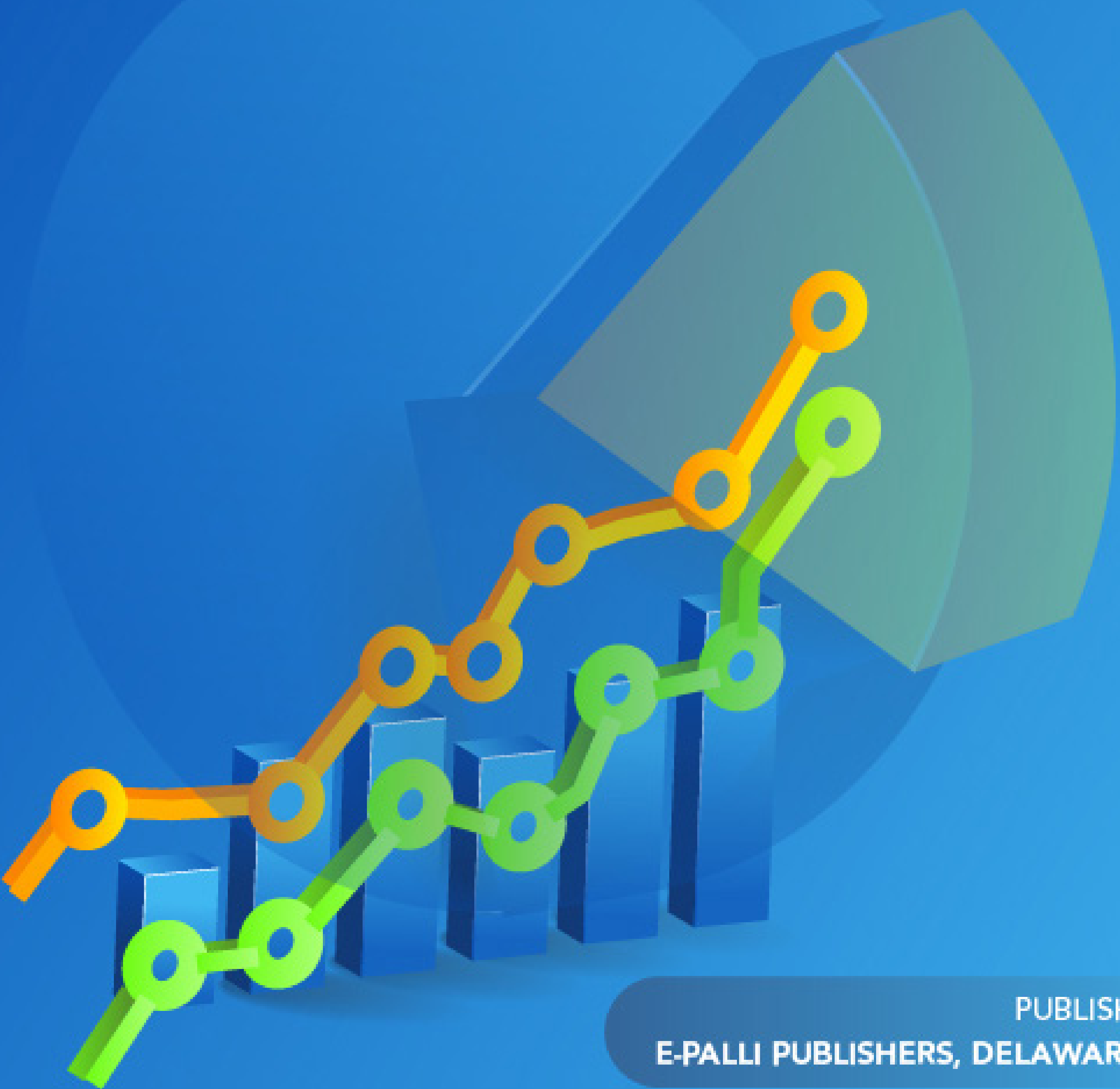

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Ordinary Least Square, the cornerstone of Econometric Theory; A literature Inquiry

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ABSTRACT

The widespread application of Ordinary Least Squares (OLS) is increasingly challenged by assumption violations, numerical instability, and inefficiencies in complex data structures. This review systematically explores the historical evolution, strengths, limitations, and modern adaptations of OLS in contemporary econometric practice. Following a structured scoping review methodology, this study synthesises literature on OLS and its alternatives. The review identifies key themes, including the historical development of OLS, its theoretical foundations, empirical strengths and weaknesses, and emerging econometric techniques that address its limitations. Thematic coding and a comparative analysis of alternative estimation methods are applied to critically assess the role of OLS in modern econometrics. The findings highlight that while OLS remains a robust estimation technique under classical assumptions, it faces significant challenges in practical applications. Studies indicate that OLS is particularly limited in handling multicollinearity, heteroscedasticity, endogeneity, and non-linear relationships. Alternative methods such as Generalized Least Squares (GLS), Instrumental Variables (IV), Maximum Likelihood Estimation (MLE), Ridge Regression, and machine learning-based techniques provide improved estimation in scenarios where OLS fails. The review further identifies an ongoing methodological shift where OLS is increasingly integrated with modern econometric techniques rather than being used in isolation. OLS continues to serve as a fundamental econometric tool, particularly in well-behaved datasets. However, its role is evolving as researchers incorporate robust statistical techniques to mitigate its limitations. Future research should focus on the empirical trade-offs between OLS and modern alternatives, the integration of OLS with machine learning approaches, and the ethical implications of model selection in econometric analysis.

INTRODUCTION

Ordinary Least Squares (OLS) has played a significant role in econometrics for centuries with many of the field's theoretical and applied advances relying on its principles (Harefa *et al.,* 2023). Its use has been synonymous with statistical rigour in the analysis of linear relationships (Deligonul *et al.,* 2009). Although the original authorship of the technique remains a subject of debate, its origins are generally attributed to the seminal contributions of Carl Friedrich Gauss and Adrien-Marie Legendre (Hu, 2023; Aldrich, 1998; Plackett, 1972). Subsequently, the Gauss-Markov theorem represents the culmination of further theoretical refinements that were implemented over time to advance the understanding of its statistical properties (Shaffer, 1991; Hansen, 2022).

This Gauss-Markov theorem asserted that OLS is the Best Linear Unbiased Estimator (BLUE), under the assumption of linearity, exogeneity, homoscedasticity, and the absence of multicollinearity (Hallin, 2014; Chipman, 2011). According to this theorem, OLS can be said to be the most efficient choice among all the linear and unbiased estimators of regression coefficients, given that it has the lowest variance. This proposition provided a robust framework for addressing economic questions with simplicity and intuitive appeal made it the default estimation method for decades. However, the historical dominance of OLS in econometrics is not only a matter of technical convenience; it provides the fundamental basis for understanding the causes behind economic phenomena (Bell, 2015).

OLS has been regarded as the foundation of econometrics (Hu, 2023; Bell, 2015). However, this assertion is not without dispute, leading to the development of other techniques (Freedman, 2025). More often than not, co-integration techniques can be adopted depending on the data properties of the variables (Okeowo, 2023; Okeowo & Awotade, 2024; Okeowo, 2023; Okeowo & Ozekhome, 2020; Ozekhome & Okeowo, 2023; Okeowo *et al.,* 2025).). As the field began to grapple with the limitations of econometrics, the methodological landscape diversified beyond OLS (Freedman, 2025; Phillips, 2003; Krämer & Hassler, 1998). For example, some of the challenges emerged in practical applications, especially when the stringent assumptions underlying OLS were violated (Wooldridge, 2010). Issues such as endogeneity compromise the consistency of OLS estimates (French & Popovici, 2011). Similarly, multicollinearity and heteroscedasticity distort the efficiency of parameter estimation, while the rise of non-linear relationships in complex datasets revealed OLS's inability to accommodate modern data structures (Wooldridge, 2010). The proliferation of alternative estimation methods, which are not limited to Generalized Least Squares (GLS), Instrumental Variables (IV), Maximum

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Likelihood Estimation (MLE), and machine learning approaches, user significant advancement in the field. These alternatives address the limitations of OLS, often offering superior performance under conditions where OLS fails (Ito, Noda & Wada, 2022). The ensuing evolution raises critical questions as to whether OLS can be regarded as the cornerstone of econometric theory (Islamov, Turdibaeva & Yusupov, 2022).

The shift reflects broader epistemological debates highlighted by Hasan and Fumerton (Hasan & Fumerton, 2000), in line with the question: Should foundational status be ascribed based on historical importance, or should it depend on continued practical and theoretical relevance in addressing contemporary challenges? Therefore, given that advancements in computational power and data availability have reshaped the empirical landscape around econometrics, a contemporary knowledge of the relevance of OLS is necessary to assess its continued applicability, limitations, and role in modern econometric methodologies [Ouattara *et al.,* 2021). This is moreover justifiable because OLS remains a fixture in econometrics that is taught as the foundational tool in virtually every introductory econometrics course (Hu, 2023). Moreover, the theories of causality and identification, such as the Rubin Causal Model and the focus on structural econometrics, have shifted attention from purely statistical properties to the interpretability and validity of estimates (Hübner, 2023).

The purpose of this scoping review is to critically engage with the debate by systematically mapping the existing literature with a view to addressing the overarching research question: Is Ordinary Least Squares (OLS) the cornerstone of econometric theory? Specifically, this review has three objectives. First, it aims to investigate the historical development of OLS and evaluate the theoretical foundations that established its preeminence. Second, it seeks to examine OLS's strengths and limitations, focusing on its ability to deliver reliable and unbiased estimates under varying conditions. Third, it explores the emergence and implications of alternative methods, evaluating their contributions and how they challenge or complement the role of OLS. Considering the breadth and depth of the body of literature with respect to the subject at hand, a scoping review is warranted to address the objectives and the research question of this study. Guided by these objectives, the review aims to assess the evolving relevance of OLS within the broader context of econometric theory and practice.

MATERIALS AND METHODS

Scoping Review Framework

To enhance the transparency, rigour, and reproducibility, this scoping review generally follows the guideline of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR), a standardized methodological framework designed for scoping studies. Developed by Tricco *et al.* (2022), PRISMA-ScR builds upon the PRISMA guidelines used for systematic reviews but is specifically tailored to scoping reviews, which aim to map the breadth of existing literature rather than derive statistical conclusions. PRISMA-ScR provides a structured approach to identifying, screening, and synthesizing relevant studies, ensuring that the review process is systematic and replicable. It outlines 22 essential reporting items that guide each stage of the review, including the definition of research objectives, the development of a comprehensive search strategy, the application of eligibility criteria, and the systematic extraction and synthesis of data.

Search Strategy and Data Sources

The literature search was conducted across a wide range of academic and grey literature databases was utilised. These included JSTOR, for historical and foundational texts; Science Direct, for journal articles in econometrics; Springer Link and Taylor & Francis Online, for academic books and methodological studies; and Google Scholar, to capture grey literature such as working papers and preprints. Additional sources like ProQuest, Econ Lit, Wiley Online Library, and SSRN provided access to emerging research. Web of Science and Emerald Insight ensured inclusion of interdisciplinary and applied studies while Opengrey facilitated the inclusion of credible grey literature.

The search strategy employed a structured combination of keywords and Boolean operators to ensure targeted and comprehensive retrieval of relevant studies. Core search terms included "Ordinary Least Squares," "OLS cornerstone," "econometric theory," "OLS limitations," "econometric methods," and "foundational principles of OLS". Boolean operators such as AND, OR, and NOT were used to refine the searches, for example, combining "Ordinary Least Squares" AND "econometric theory" to focus on studies linking OLS to econometric methodologies, and using "OLS limitations" OR "econometric methods" to broaden the scope for critiques and comparisons. Furthermore, truncation and wildcard searches were incorporated to capture variations in search terms, such as econometr to encompass "econometrics" and "econometricians".

The full search query used in Google Scholar is presented in Appendix I. The most recent search was executed on January 28, 2025. Each database search was conducted with filters applied to restrict results to English-language sources and studies published between 1805, when Gauss was purported to have introduced the method, and 2025. This range was considered to encompass both historical significance and contemporary applications. Furthermore, only English-language sources were included to ensure consistency and accessibility. More also, the search strategy considered only peer-reviewed journal articles, academic books, conference papers, and grey literature with substantial academic contributions were included. While the prioritization of academic journal studies and peer-reviewed sources maintains the scholarly rigour and credibility of the review, the inclusion of grey literature further enhances the depth of the analysis by incorporating emerging discussions and pre-publication research.

Screening and Eligibility

The inclusion and exclusion criteria were carefully developed to ensure that the review remained focused on addressing the research question. These criteria are summarised in the Table 1.

Table 1: Inclusion and Exclusion Criteria

Criteria	**Inclusion**	**Exclusion**
Content	Studies explicitly discussing the theoretical foundations of OLS.	Studies employing OLS without engaging with its theoretical underpinnings.
Critique	Papers critiquing OLS or highlighting its limitations in econometric practice.	Articles outside the scope of econometrics, such as those focused on non-econometric statistical methods.
Comparisons	Literature comparing OLS to alternative methods, such as GLS, IV, MLE, or machine learning.	Studies with purely applied results where OLS is used without a critical or comparative focus.
Language	English-language studies.	Non-English studies, due to resource constraints in translation.
Publication Type	Journal articles, academic books, conference papers, and grey literature.	Blog posts, opinion pieces, and articles without substantial academic contribution.

The selection of sources of evidence for this scoping review followed a structured and transparent approach to ensure consistency and reliability in the inclusion process. The process was conducted in accordance with the PRISMA-ScR guidelines and consisted of two main stages: (1) title and abstract screening and (2) full-text review. The initial search results were imported into Zotero, a free and open-source reference management system, where duplicate records were identified and removed. In the first stage, titles and abstracts of all retrieved records were screened against the inclusion and exclusion criteria to determine relevance. This process was carried out independently by two reviewers to minimise bias. Studies that met the initial screening criteria were subjected to a full-text review to confirm their eligibility for inclusion in the final analysis. This second stage also involved dual independent screening where full texts were independently assessed by two reviewers. Disagreements were resolved through discussion, and in cases where consensus could not be reached, a third reviewer was consulted. Inter-rater reliability was assessed during pilot screening to ensure consistency in study selection. This rigorous selection process ensured that only studies directly contributing to the theoretical and methodological discourse on OLS were included in the final synthesis.

Data Charting and Analysis

A structured data charting framework was employed to systematically chart key information from the included studies, ensuring consistency and comprehensiveness in the review process. The charting process utilised calibrated forms that were deisgned and tested prior to implementation to ensure reliability and uniformity in data extraction. Data charting was conducted independently by two reviewers, with discrepancies resolved through discussion and, where necessary, consultation with a third reviewer to enhance accuracy and mitigate potential biases. The extracted data fields included bibliographic details including the author(s), year of publication, title, and source to provide clear referencing and context for each study. Furthermore, each study was categorised by type to distinguish between different methodological approaches. The focus areas of the studies were also documented, encompassing themes such as the historical role of OLS, critiques of its assumptions, its strengths and limitations, or its comparison with alternative methods. Key findings were summarised to capture the main conclusions and arguments presented in each study, offering valuable insights into the ongoing discourse around OLS.

The review employed a deductive thematic data analysis, where predefined themes were derived directly from the research objectives and questions. This deductive approach ensured that the extracted data was systematically aligned with the scope of the review, enabling the categorisation of findings into meaningful and focused themes that directly addressed the research questions. To facilitate this process, Taguette, a qualitative data analysis tool, was utilised. Taguette provided an efficient platform for coding and organising the extracted data according to the predefined thematic categories, ensuring consistency and traceability throughout the analysis. Thematic mapping was employed to structure the findings of the review into a set of predefined categories, ensuring alignment with the research objectives and enabling a focused analysis of the role of Ordinary Least Squares (OLS) in econometric theory. The first category, Historical and Theoretical Foundations, included studies that traced the origins and development of OLS, highlighting its pivotal role in shaping early econometric theory. These studies provided insights into the theoretical basis of OLS, including its mathematical properties under the Gauss-Markov theorem, and established its status as a cornerstone of econometric methodology.

The second category, Strengths and Pedagogical

Relevance, focused on works that highlighted the simplicity, interpretability, and widespread adoption of OLS in econometric education. These studies underscored OLS's accessibility, which has made it an indispensable tool for teaching foundational econometric principles and introducing statistical modeling to students and practitioners. The third category, Critiques and Limitations, addressed research examining the shortcomings of OLS. These studies explored key challenges such as violations of the method's assumptions, including endogeneity, multicollinearity, and heteroscedasticity, which often undermine the reliability of OLS estimates in applied contexts. The limitations of OLS were critically evaluated in light of its theoretical assumptions and its performance under real-world conditions.

The fourth category, Alternatives and Advancements, encompassed studies discussing alternative methods developed to address the limitations of OLS. This included Generalized Least Squares (GLS), Instrumental Variables (IV), Maximum Likelihood Estimation (MLE), and modern techniques such as machine learning. These studies evaluated the ability of these methods to handle complex data structures, mitigate the effects of assumption violations, and provide robust estimates in scenarios where OLS is inadequate. The final category, Evolving Role in Modern Econometrics, explored how OLS has been adapted or complemented by advanced methodologies in contemporary econometric practice. This category included discussions on hybrid models that integrate OLS with modern techniques, its continued relevance in specific applications, and the contexts in which it has been supplanted by more sophisticated tools.

RESULTS AND DISCUSSION

Descriptive Analysis

Selection of Sources of Evidence

The PRISMA flowchart shown in Figure 1 presents a visual summary of the study selection process, outlining the stages of identification, screening, eligibility assessment, and final inclusion.

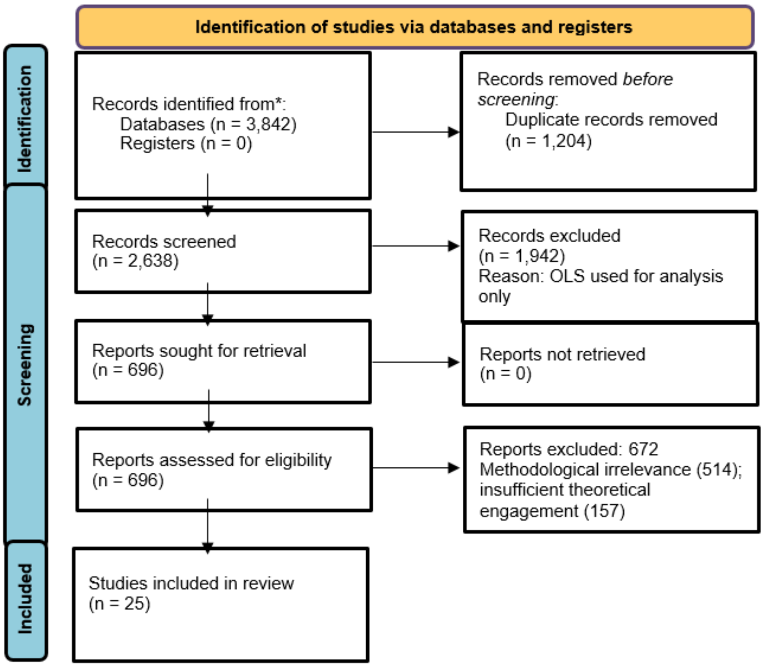

Figure 1: PRISMA flowchart diagram for the inclusion of studies

The initial search process yielded 3,842 records across all databases. After removing 1,204 duplicate entries, a total of 2,638 unique records were screened based on their titles and abstracts. During this initial screening phase, 1,942 records were excluded for failing to meet the inclusion criteria. The most common reasons for exclusion were studies that employed OLS without any theoretical discussion, papers that focused solely on applied regression models without engaging with econometric theory, or studies that were outside the field of econometrics, such as those dealing with engineering or medical statistics.

Following this initial screening, a full-text review was conducted for 696 shortlisted studies to assess their relevance more rigorously. At this stage, 672 studies were excluded for various reasons. The most significant factor leading to exclusion was methodological irrelevance (n = 514), where studies applied OLS in non-econometric disciplines and used statistical methods unrelated to econometrics. Another 157 studies were excluded due to their insufficient theoretical engagement as they merely presented mathematical derivations. After this thorough review process, 25 studies were included in the scoping review [23-47]. These selected studies provided a well-rounded perspective on OLS, encompassing its historical foundations, theoretical strengths, critiques, and comparisons with alternative estimation techniques.

Characteristics of the Included Studies

The elaborate table of the characteristics of the included studies is presented in Appendix II. The included studies exhibit a diverse methodological and conceptual landscape, reflecting the ongoing discourse on the role of Ordinary Least Squares (OLS) in econometrics. A significant proportion of the studies examine OLS's theoretical underpinnings, statistical properties, and historical development. Tricco *et al.,* 2018; Merriman, 1877; Michaelides, 2024; Sheynin, 2014; Stigler, 1981). These studies trace OLS's origins to the contributions of Gauss and Legendre, exploring the theoretical justifications for its Best Linear Unbiased Estimator (BLUE) property under the Gauss-Markov theorem. Notably, some studies question whether OLS remains foundational in light of modern econometric advancements (Mahaboob *et al.,* 2018; Michaelides, 2024), while others focus on its historical and mathematical formulation without empirical validation (Merriman, 1877; Sheynin, 2014; Stigler, 1981).

The review also includes empirical and methodological studies that critically assess OLS in real-world econometric applications, highlighting its strengths and limitations in different contexts (Abdullahi & Yahaya, 2015). A major concern raised in several studies is the violation of OLS assumptions, particularly when dealing with heteroscedasticity, multicollinearity, endogeneity, and nonlinearity (Abdullahi & Yahaya, 2015; Anderson & Schumacker, 2003; Banerji, 2011). For instance, empirical research demonstrates that OLS is inefficient when applied to categorical or limited dependent variable models, such as the Linear Probability Model (LPM) (Horrace & Oaxaca, 2006). Similarly, measurement error biases and the implications of signal loss errors in macroeconomic applications further challenge OLS's reliability in empirical settings (Nalewaik, (2008).

Several studies propose alternative estimation methods to address the limitations of OLS, particularly in cases where its assumptions fail (Abdullahi & Yahaya, 2015). These alternatives include robust regression methods, such as Quantile Regression (QR), Least Absolute Value (LAV) estimation, and Generalized Least Squares (GLS), which offer superior performance under conditions of heteroscedasticity and outlier contamination (Anderson & Schumacker, 2003). Other studies emphasize numerical instability and computational challenges associated with OLS, particularly in ill-conditioned data, and recommend the use of Singular Value Decomposition (SVD), Tikhonov Regularization (Ridge Regression), and Kalman Filtering as potential remedies (Watson, 1983). Comparative assessments of OLS against Bayesian, Stein-type, and principal component regression approaches further underscore the increasing shift toward alternative estimation techniques (Cox & Oaxaca, 2008)].

Moreover, several studies adopt a simulation-based approach to examine the efficiency and robustness of OLS in various data environments. Monte Carlo simulations are widely used to test OLS performance relative to robust regression methods (Anderson & Schumacker, 2003), ridge regression (Dempster *et al.,* 1977), and alternative estimation models. These simulation-based studies demonstrate that OLS performs suboptimally in the presence of multicollinearity, small sample sizes, and high-dimensional data, raising concerns about its applicability in modern econometric modeling (Anderson & Schumacker, 2003).

A subset of studies also critiques OLS's role in structural modeling and path analysis, particularly in disciplines where latent variables and measurement errors are of concern (Kline & Klammer, 2001). Here, comparisons between OLS and structural equation modeling (SEM) suggest that OLS is ill-equipped to handle measurement errors and interdependent relationships, reinforcing arguments for its limited applicability outside classical econometrics. Similarly, discussions of OLS in panel data models reveal that its efficiency loss compared to alternative estimators, like the Best Linear Unbiased Estimator (BLUE), remains a persistent issue.

In addition to methodological concerns, the included studies engage with the philosophical and conceptual aspects of OLS in econometrics (Merriman, 1877). Some research presents OLS as a structured method of measurement, drawing parallels with measurement theories in the natural sciences. However, other works question whether OLS is an epistemological anchor in econometrics or simply a convenient estimation technique that has persisted due to historical inertia rather than empirical superiority. These studies highlight the tension between tradition and innovation in econometric methodology, emphasizing the need for more adaptive estimation techniques in contemporary economic research.

A recurring theme in the reviewed literature is the institutional persistence of OLS in econometrics education and research. While empirical evidence increasingly highlights its limitations, OLS remains the default method taught in introductory econometrics courses and is widely used in policy evaluation, financial modeling, and applied research (Helmreich & Krog, 2017). This raises important questions about whether econometric training adequately equips researchers with the tools to assess OLS's limitations and explore alternative methods. Despite the availability of Generalized Method of Moments (GMM), Maximum Likelihood Estimation (MLE), and Machine Learning techniques, OLS continues to dominate econometric practice, reflecting a methodological conservatism in the discipline.

Quantitative Commentary

A visual representation of the number of studies published over time is provided to in Figure 2 to illustrate trends in research focus on OLS and its alternatives. The increasing number of publications from the 1990s onwards indicates growing concerns about the robustness of OLS and the search for more flexible alternatives. While early studies largely affirmed the foundational nature of OLS, later studies have shifted towards investigating its limitations

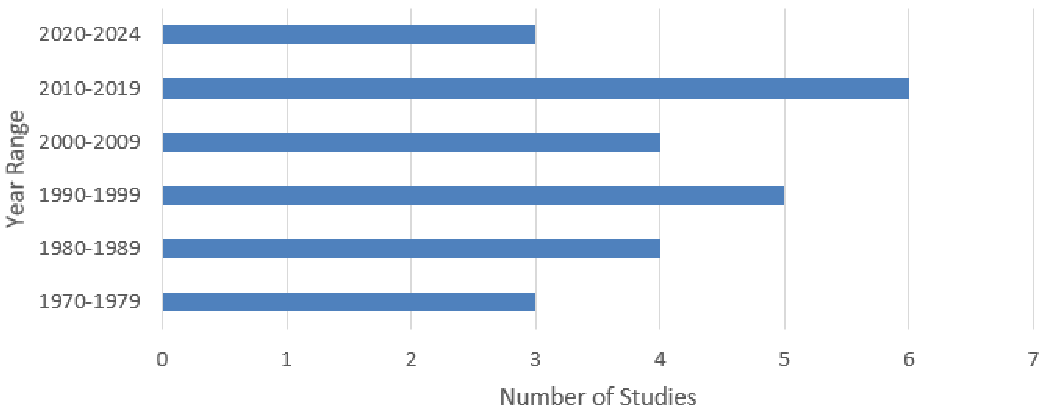

Figure 2: Timeline of publications

and proposing alternatives. The declining number of publications post-2020 may suggest that the debate has matured, with established alternatives being increasingly adopted in applied econometrics.

The studies reviewed focus on different themes related to OLS, ranging from its foundational justifications to critiques and alternatives. These are illustrated in Figure 3. The dominance of studies critiquing OLS and investigating alternative methods reflects a broader shift in econometrics toward robustness in regression modeling. The relative scarcity of studies focused on methodological comparisons (4%) suggests that while alternatives are explored, direct empirical comparisons between OLS and alternative techniques remain underdeveloped.

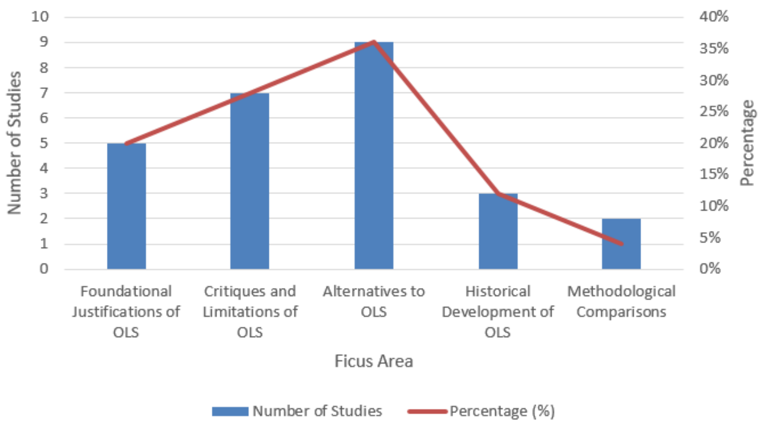

Figure 3: Focus areas

The geographical focus of these studies presented in Figure 4 highlight the dominance of Western-centric research in econometrics. The concentration of studies from the United States suggests a strong academic focus on OLS within American institutions, which aligns with the broader dominance of econometrics research in North America. Notably, Germany, the UK, and Canada also contribute significantly to the discourse, emphasizing their roles in theoretical and empirical econometrics. The dominance of contributions from the United States, the United Kingdom, and Germany highlights the longstanding influence of these nations in econometric theory and applied research. However, there is also representation from emerging economies, such as Nigeria and India, indicating growing academic engagement in methodological advancements in econometrics beyond Western contexts. While OLS is globally applied, the limited presence of studies from developing economies, such as Nigeria with only one study, highlights potential gaps in localized economic modeling where OLS assumptions may not hold due to issues like data scarcity and institutional inefficiencies.

The data presented in Figure 5 indicate that while OLS remains central to econometric methodology, critiques of its assumptions and efforts to identify superior estimation techniques dominate the literature. The studies questioning OLS focus on key econometric challenges, including endogeneity, multicollinearity, and model misspecification. Additionally, several studies highlight the emergence of machine learning and Bayesian approaches as viable alternatives to OLS in handling high-dimensional and non-linear datasets.

Thematic Mapping

The thematic matrix in Table 2 provides a well-structured synthesis of key themes surrounding Ordinary Least Squares (OLS), tracing its historical development, theoretical strengths, limitations, and evolving role in modern econometrics.

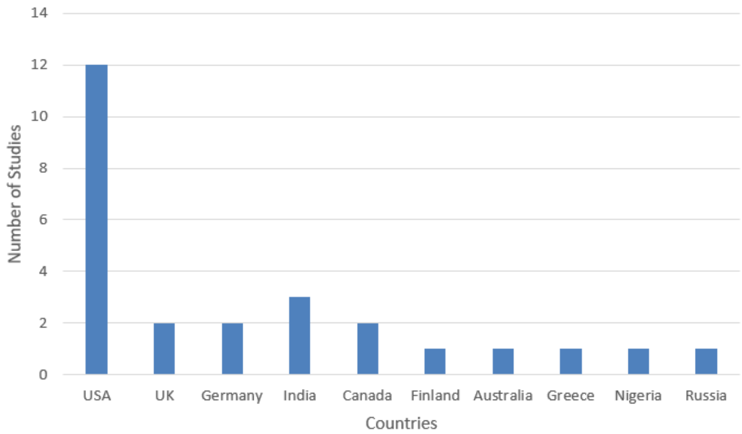

Figure 4: Geographical context of included studies

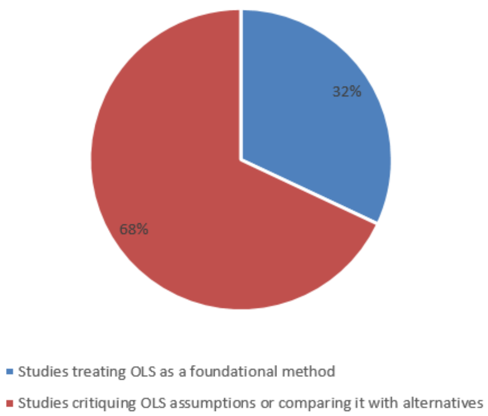

Figure 5: Proportion of studies addressing OLS as foundational

Table 2: Thematic matrix

Theme	Key Findings
Historical Context of OLS	OLS developed as a foundational estimation technique in regression analysis, originating from Legendre and Gauss. Theoretical justifications such as the Gauss-Markov theorem established OLS as BLUE.
Strengths of OLS	OLS is efficient and unbiased under classical assumptions. Its simplicity and ease of implementation make it widely applicable. The method provides clear interpretations of regression coefficients.
Limitations of OLS	Assumptions such as homoscedasticity, exogeneity, and lack of multicollinearity are often violated in practice, leading to inefficiency and biased estimates. OLS performs poorly in dynamic models, limited dependent variables, and nonlinear settings.
Numerical Stability Issues	OLS regression can become unstable when applied to ill-conditioned data. High sensitivity to small errors and instability in collinear regressors reduce reliability. Corrective measures include Singular Value Decomposition (SVD) and Ridge Regression.
OLS in Limited Dependent Models	OLS produces biased and inconsistent estimates when applied to limited dependent variable models (e.g., Tobit, binary outcomes). Alternative methods such as Maximum Likelihood Estimation (MLE) and Generalized Least Squares (GLS) perform better.
Comparison with Robust Methods	Studies find that robust regression techniques (e.g., Quantile Regression, MM-estimation, and Huber's M-estimation) outperform OLS when assumptions are violated. These alternatives reduce bias and improve efficiency under non-Gaussian distributions.
OLS vs. Modern Alternatives	Alternative methods such as Ridge Regression, Kalman Filtering, and Bayesian estimation perform better under multicollinearity and non-stationary conditions. Machine learning-based techniques offer greater flexibility.

OLS in Market-Based Analysis	Experimental market data reveal that OLS performs well in competitive equilibrium settings but poorly in double auction and posted offer markets, where 2SLS and D2SMAD are more robust.
OLS in High-Dimensional Data	Principal Component Regression (PCR) and Ridge Regression provide superior estimation in the presence of multicollinearity, reducing overfitting while maintaining predictive power.
Bias in OLS Estimation	Measurement errors, autocorrelation, and dynamic relationships introduce biases in OLS. Simulation-based studies confirm that Ridge Regression and Stein-type estimators outperform OLS in biased data settings.
OLS in Path Analysis	OLS does not account for interdependent variables in path analysis. LISREL and Structural Equation Modeling (SEM) provide superior estimation by incorporating latent variables and measurement errors.
OLS in Macroeconomic Models	Lack of Signal Error (LoSE) in macroeconomic data results in biased OLS estimates, contradicting classical measurement error assumptions. This limits the applicability of OLS in macroeconomic forecasting.
OLS in Financial Markets	In financial econometrics, Weighted Least Squares (WLS) and heteroskedasticity-consistent estimators outperform OLS when modeling abnormal returns. GLS and portfolio-based regression techniques offer improved inference.
Evolving Role of OLS	OLS remains a benchmark method but is increasingly integrated with modern techniques such as machine learning, Bayesian regression, and shrinkage methods. The shift from OLS dominance to a hybrid econometric approach is evident in applied research.

Discussion

A significant body of research emphasizes that OLS relies on strong assumptions that often do not hold in empirical data. The classical assumptions are frequently violated in real-world datasets, leading to inefficiency and bias in OLS estimates (Anderson & Schumacker, 2003). Studies have shown that when heteroskedasticity is present, OLS fails to provide efficient estimates, making robust regression techniques, such as Quantile Regression (QR) and Ridge Regression, preferable in such cases. Multicollinearity is another critical issue, as it inflates variance and destabilizes OLS estimates, reducing the precision of coefficient estimates. To address these shortcomings, alternative estimation methods such as Principal Component Regression (PCR) and Generalized Least Squares (GLS) have been recommended [Mukhopadhyay & Schwabe, 1998).

Empirical comparisons between OLS and alternative estimation techniques reveal that while OLS performs optimally under its classical assumptions, it is outperformed by robust regression methods when those assumptions are violated. Monte Carlo simulation studies have demonstrated that MM-estimators, Huber's M-estimation, and Least Absolute Value (LAV) regression provide superior performance in handling influential data points and reducing bias. Quantile Regression has been particularly effective in dealing with skewed data and heteroskedasticity by estimating conditional quantiles rather than the mean, offering a more comprehensive understanding of data distribution. Additionally, Bayesian shrinkage methods and Stein-type estimators have shown notable improvements over OLS in cases of multicollinearity, reducing mean squared errors and enhancing coefficient stability (Vinod, (1978).

Despite its limitations, OLS remains widely used due to its simplicity and interpretability. Unlike more complex regression techniques, OLS has closed-form solutions that are easy to compute and understand. However, with the advancement of computational resources, the justification for using OLS purely for its efficiency has weakened. Techniques such as Kalman Filtering and Ridge Regression, which were once computationally demanding, are now feasible due to improved algorithmic efficiency and computational power (Watson, 1983). Some studies argue that the continued reliance on OLS stems more from historical inertia rather than empirical superiority, suggesting that econometric training should emphasize alternative methods more prominently.

The effectiveness of OLS varies depending on the context of application. In financial econometrics, Generalized Least Squares (GLS) is often preferred over OLS due to its ability to handle serial correlation in time-series data. Similarly, econometric studies involving categorical dependent variables have found that OLS is inappropriate, as it fails to constrain probability estimates within the interval, making logistic and probit regression superior choices. In macroeconomic applications, OLS has been criticized for its susceptibility to measurement errors, with studies highlighting how signal loss errors distort parameter estimates, leading to incorrect inferences. On the other hand, studies in structural equation modeling (SEM) suggest that OLS is ill-equipped to handle latent variables and measurement errors, reinforcing the need for SEM-based approaches in cases of complex interdependencies.

Historically, OLS has been a cornerstone of econometric analysis, forming the basis of foundational statistical methodologies (Sheynin, 2014). However, contemporary research increasingly views OLS as a benchmark method rather than the gold standard for regression analysis.

While it remains widely used in educational settings and introductory econometric courses, alternative estimation techniques are becoming more prevalent in applied research, particularly in policy evaluation and predictive modeling. The persistence of OLS in econometric research, despite its widely documented limitations, raises concerns about whether econometric training sufficiently equips researchers with the tools to critically assess its applicability and explore more robust alternatives (Michaelides, 2024).

Limitations

Despite offering a comprehensive synthesis of the literature, this scoping review has several limitations that primarily stem from the included studies. One of the fundamental limitations of this scoping review is the absence of a rigorous quality appraisal of the included studies. Unlike systematic reviews, which assess the reliability, validity, and methodological robustness of each study, this review does not critically evaluate the strength of evidence presented. Consequently, weaker or methodologically flawed studies may carry the same weight as high-quality empirical research. This could introduce bias, particularly in areas where findings are contested, such as the effectiveness of alternative regression methods compared to OLS.

Additionally, the review relies primarily on English-language publications, which could introduce linguistic and regional biases. Studies published in other languages or from less dominant academic traditions may offer alternative perspectives on OLS but are not captured here. Furthermore, while the review acknowledges that OLS has limitations and discusses alternatives such as GLS, MLE, and machine learning-based techniques, the exploration of these alternatives is not comprehensive. Considering its widespread implementation across diverse disciplines, OLS presents a problematic subject for a review study due to the difficulty in differentiating studies where it was a subject of discuss and where it was only implemented in analysing data. This may have affected the breadth and depth of this study. Moreover, the review does not fully incorporate discussions on how advancements in computational methods, big data analytics, and artificial intelligence are reshaping econometric estimation.

Research Gaps and Future Directions

Despite the extensive literature on OLS and its alternatives, several gaps remain, highlighting areas for future research:

1. Comparative Performance Across Diverse Datasets: While many studies evaluate OLS in controlled settings, fewer systematically compare its performance with alternative methods across diverse real-world datasets. Future research should explore the empirical trade-offs between OLS and methods such as Ridge Regression, Quantile Regression, and Bayesian estimators in applied economic and financial contexts.
2. Integration with Machine Learning and Big Data Methods: The growing availability of high-dimensional data has led to increased interest in hybrid models combining OLS with regularisation techniques, ensemble learning, and deep learning. Future research should investigate how OLS can be adapted or integrated into machine learning pipelines to improve predictive performance while maintaining interpretability.
3. Practical Implications for Policymaking and Industry: While OLS remains widely used in policy evaluation, finance, and social sciences, its limitations in handling complex relationships require greater scrutiny. Further studies should assess how OLS-based models influence decision-making in regulatory and business environments and whether alternative methods provide more robust insights.
4. Advancements in Robust and Adaptive Estimation Methods: The effectiveness of OLS in real-world applications often depends on addressing issues such as heteroscedasticity, autocorrelation, and endogeneity. Future work should focus on developing adaptive estimation techniques that dynamically adjust to data characteristics, enhancing the applicability of OLS in evolving econometric frameworks.
5. Addressing Ethical and Transparency Concerns in Model Selection: With the increasing use of econometric models in high-stakes decision-making, there is a need for research into the ethical implications of using OLS versus more complex methods. Transparency, fairness, and interpretability should be key considerations in developing guidelines for model selection.

CONCLUSION

This scoping review has examined the historical development, strengths, limitations, and evolving role of OLS in econometrics. While OLS remains a foundational estimation technique due to its simplicity, interpretability, and well-established theoretical properties, its limitations in handling real-world complexities necessitate the adoption of alternative and complementary methods. Issues such as assumption violations, numerical instability, and inefficiency in high-dimensional and limited dependent variable models challenge the reliability of OLS in various applications. As a result, modern econometric practice increasingly integrates OLS with robust, machine learning-based, and Bayesian approaches to enhance estimation accuracy and flexibility. Rather than being replaced, OLS is evolving within a broader methodological landscape, where its role is context-dependent. In traditional econometric models with well-behaved data, OLS continues to provide valuable insights. In contrast, in high-dimensional, non-linear, or structurally complex settings, more sophisticated methods are often necessary. Future econometric research should, therefore, focus on leveraging the strengths of OLS while integrating advances in computational techniques to ensure robust, interpretable, and practical model selection.

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Appendix I: Combined Search Query

("Ordinary Least Squares" OR "OLS regression" OR "Least Squares Method" OR "linear regression estimat*" OR "OLS model" OR "OLS estimat*")

AND

(("historical development" OR "histor*" OR "evolution" OR "origin*" OR "Gauss" OR "Legendre" OR "statistical origin*" OR "early application*" OR "develop* of OLS")

OR

("limitation*" OR "bias*" OR "weakness*" OR "criticism*" OR "pitfall*" OR "assumption* fail*" OR "multicollinear*" OR "heteroscedastic*" OR "endogen*" OR "overfit*" OR "mis-specification*" OR "OLS inefficien*")

OR

("application*" OR "use case*" OR "applied econometric*" OR "real-world implement*" OR "economic model*ing" OR "economic model*ling" OR "policy evaluat*" OR "forecast*" OR "time-series analys*" OR "market analys*" OR "financial econometric*" OR "panel data analys*")

OR

("alternative method*" OR "Generalized Least Squares" OR "Generalised Least Squares" OR "GLS regression" OR "Instrumental Variable*" OR "IV regression" OR "Maximum Likelihood Estimat*" OR "MLE" OR "Bayesian regression" OR "Machine learning regression" OR "Ridge regression" OR "Lasso regression" OR "Quantile regression" OR "Regulari?ed regression" OR "Robust regression" OR "Nonparametric method*"))

AND

("econometric model*ing" OR "econometric model*ling" OR "statistical infer*" OR "regression analys*" OR "prediction model*" OR "econometric estimation technique*" OR "statistical estimat*" OR "linear model*")

Appendix II: Data Charting

S/N	Bibliographic Details	Aim	Study Type	Focus Area	Methodological Approach	Key Findings	Limitations of Study
1.	Abdullahi, I., & Yahaya, A. (2015). Analysis of Quantile Regression as Alternative to Ordinary Least Squares. International Journal of Advanced Statistics and Probability, 3(2), 138. https://doi.org/10.14419/ijasp.v3i2.4686	The study aims to investigate quantile regression (QR) as an alternative to Ordinary Least Squares (OLS), particularly in cases where OLS assumptions are violated. It seeks to demonstrate how QR can provide a more robust estimation technique by capturing variations across different quantiles rather than focusing solely on the conditional mean, as OLS does. The study evaluates goodness-of-fit measures, model validity, and estimation accuracy using real-world data to highlight the strengths of QR over OLS.	Empirical and Methodological	Alternatives to OLS, Critiques and Limitations	Quantitative comparison between OLS and Quantile Regression (QR) using real-world data on fuel consumption (miles per gallon in highway driving). Statistical software packages (EViews and Statgraphics) were used for analysis.	The study compares OLS with Quantile Regression (QR) to determine which method provides a better fit in regression analysis. OLS performs well in explaining the mean relationship but struggles with non-constant variance (heteroscedasticity) and fails to capture variations across the distribution. QR overcomes these limitations by providing conditional quantile estimates, making it more robust in dealing with heteroscedasticity and outliers. The study concludes that OLS has limitations in applied settings and that QR is often a more reliable alternative, suggesting that OLS should not always be the default choice in econometrics.	Quantile Regression (QR) requires a sufficiently large dataset to produce stable and reliable estimates, particularly for extreme quantiles. In small samples, QR results may be inconsistent or highly variable.

2.	Anderson, C., & Schumacker, R. E. (2003). A Comparison of Five Robust Regression Methods with Ordinary Least Squares Regression: Relative Efficiency, Bias, and Test of the Null Hypothesis. Understanding Statistics, 2(2), 79–103. https://doi.org/10.1207/s15328031us0202_01	The study aims to compare five robust regression methods with Ordinary Least Squares (OLS) in terms of relative efficiency, bias, and statistical significance testing under various outlier configurations. The goal is to determine whether OLS remains an optimal estimator when data includes outliers and assumption violations or if alternative robust regression methods provide superior performance.	Empirical and Methodological. The study uses Monte Carlo simulations to evaluate the robustness of OLS compared to five alternative regression methods.	Critiques and Limitations of OLS Alternatives to OLS (e.g, Least Absolute Value (LAV), MM-estimation, Huber's M-estimation, Generalized MM-estimation, Least Trimmed Squares (LTS))	Monte Carlo simulations were used to generate data under 36 different outlier configurations, varying: • Sample size (60 and 180 observations). • Number of predictor variables (2, 3, or 6). • Outlier density (0%, 5%, 15%). • Outlier placement (x-axis, y-axis, or both). Five robust regression techniques were evaluated against OLS: • Least Absolute Value (LAV) • Minimum M-estimation (MM1, MM2, MM3) • Generalized MM-estimation • Huber's M-estimation • Least Trimmed Squares (LTS) The regression models were assessed based on: • Relative efficiency (comparison of estimation accuracy). • Bias (differences in coefficient estimates due to outliers). • Significance test of the null hypothesis (robust F-test used in S-PLUS software).	OLS performs poorly in the presence of outliers and produces unstable estimates when normality and homoscedasticity assumptions are violated. MM2 was the most efficient estimator with a tuning constant of 0.80, providing the most stable estimates across all data configurations. LAV had the lowest efficiency among the methods tested and was the least reliable alternative to OLS. MM1 had the lowest bias, while LAV had the highest bias, indicating that robust MM-type estimators are more reliable than OLS in handling influential data points. OLS frequently produced high Type I error rates, rejecting the null hypothesis more often than expected when outliers were present. MM-type robust regression methods consistently outperformed OLS and LAV across all three evaluation criteria: relative efficiency, bias, and hypothesis testing.	The study relies on simulated data rather than real-world datasets, which may limit its generalizability to practical econometric applications. Many robust regression methods, particularly MM-type estimators, are not widely available in standard statistical software, making their adoption more difficult for applied researchers. Robust regression methods require more computational power compared to OLS, which can be a barrier for large datasets or real-time applications

3.	Balzer, W., & Haendler, E. W. (1989). Ordinary Least Squares as a Method of Measurement. Philosophy of Economics, 30(1/2), 129–146. JSTOR. https://doi.org/10.2307/20012202	The study aims to conceptualize Ordinary Least Squares (OLS) as a method of measurement rather than solely a statistical estimation tool. It argues that OLS serves as a regression-based method of measurement, similar to fundamental measurement methods in the natural sciences. The study explores how OLS translates theoretical economic models into measurable quantities and justifies its role within the framework of theory-dependent measurement.	Theoretical and Methodological The study is philosophical and conceptual, focusing on the justification of OLS as a structured measurement tool in econometric theory.	Historical and Theoretical Foundations of OLS Conceptual Justification of OLS as a Measurement Method OLS's Role in Estimating Parameters in Econometrics	Structuralist Theory of Measurement → The study applies the structuralist view of measurement to justify OLS as a valid method of measurement. Theoretical Justification Using Measurement Models → The paper defines OLS as a regression-based measurement approach, showing how it translates abstract economic theory into empirical estimations. Comparison with Natural Science Measurement Methods → The study parallels OLS with physical measurement models, illustrating how theory-dependent measurement applies in both social and natural sciences. Application to Linear Stochastic Demand Systems → The study applies its framework to OLS estimation of parameters in stochastic demand systems, demonstrating how OLS functions as a measurement tool in applied econometrics.	OLS is not just a statistical estimator; it serves as a structured method of measurement in econometrics. OLS follows the principles of theory-dependent measurement, similar to scientific measurement models that translate theoretical constructs into observable values. OLS's justification is based on its ability to produce values that satisfy identity conditions of theoretical economic models, making it fundamental to econometric analysis. OLS provides measurable estimates for theoretical parameters in linear stochastic demand systems, confirming its role as a structured measurement method. The justification for OLS as a measurement tool requires a broader conceptual framework than classical econometric assumptions, linking it to the structuralist paradigm of measurement.	Lack of Empirical Validation – The study is purely theoretical and does not provide empirical tests or simulations to support its conceptual claims. Overgeneralization of OLS as a Measurement Tool – While the study argues for OLS's foundational role, it does not fully address cases where OLS assumptions fail, such as heteroscedasticity, endogeneity, or multicollinearity. Limited Discussion on Alternatives – The study focuses exclusively on OLS without exploring how other econometric methods (e.g., GLS, IV, MLE) compare as measurement tools.

4.	Banerji, J. (2011). The Method of (Not So) Ordinary Least Squares: What Can Go Wrong and How to Fix Them. Contemporary Physics, 52(3), 181–195. https://doi.org/10.1080/00107514.2011.563544	To analyze potential issues with Ordinary Least Squares (OLS) regression, particularly in cases where it fails due to numerical instability, and to propose alternative techniques to improve estimation accuracy.	Theoretical and numerical analysis	Limitations of OLS in real-world applications. Impact of numerical errors and ill-conditioning on regression estimates. Alternative techniques to improve the stability of OLS-based regression	Demonstrates problems with OLS using numerical examples. Examines issues such as high sensitivity to small errors and instability in ill-conditioned data. Proposes corrective methods: • Singular Value Decomposition (SVD): Decomposes the design matrix to improve stability. • Discrete Picard Condition: Helps diagnose instability in solutions. • Tikhonov Regularisation (Ridge Regression): Introduces a regularization parameter to stabilize regression estimates. • L-Curve Criterion: A graphical method to optimally choose the regularization parameter.	OLS regression can produce highly unstable and misleading estimates when applied to ill-conditioned data. The SVD-based approach helps decompose the system to identify and filter out unstable components. Tikhonov regularisation effectively stabilizes OLS estimates by introducing a controlled amount of bias. The L-curve criterion provides a systematic method for selecting the optimal level of regularization. The study emphasizes that OLS should not be blindly applied and alternative methods should be used in cases of numerical instability	The proposed alternative techniques (SVD, Tikhonov Regularisation, and L-Curve Criterion) require a deeper mathematical understanding, making them less accessible to non-experts. The effectiveness of these methods depends on correctly choosing hyperparameters, which may not always be straightforward. The study does not extensively test these techniques on large empirical datasets, limiting its applicability to real-world econometric problems.

5.	Chan, M. W. L., & Oksanen, E. H. (1987). Ordinary Least Squares Versus Principal Components Regression: Some Simulation Evidence. Empirical Economics, 12(2), 97–106. https://doi.org/10.1007/bf01972332	To compare Ordinary Least Squares (OLS) with Principal Components Regression (PCR) using simulation experiments, evaluating their performance based on mean square error (MSE) and mean absolute error (MAE) criteria.	Simulation-based comparative analysis.	Comparison of OLS and PCR in the presence of collinearity among regressors. Investigation of component selection methods for PCR. Evaluation of regression performance using MSE and MAE loss functions.	The study conducts Monte Carlo simulations to compare OLS and PCR estimators. It uses a Harrison-Rubinfeld dataset on housing prices to create a simulated environment for evaluating regression performance. It tests five component selection criteria for PCR: 1. QLS (all components retained). 2. $t^2 > 1$ criterion (maximization of R^2). 3. $t^2 > 4$ criterion (significance at the 5% level). 4. Mundlak's method (based on F-test exclusion). 5. Largest eigenvalues criterion (retaining components explaining 95% of variance). Simulations are run using a dataset of 92 observations with 13 regressors, with added collinearity in transformed regressors.	The largest eigenvalues method performed worst among the PCR estimators. When regressors were highly collinear, PCR still did not outperform OLS, contradicting expectations that PCR might handle multicollinearity better. The superiority of OLS remained when the model was transformed to introduce greater collinearity.	rankings of PCR selection methods. The findings may not generalize to situations where PCR is specifically optimized for variable selection. Only two risk functions (MSE and MAE) were used, while other performance criteria (such as bias-variance tradeoff) were not explored.

6.	Cox, J. C., & Oaxaca, R. L. (2008). Chapter 114 experimetrics: The use of market experiments to evaluate the performance of econometric estimators. Handbook of Experimental Economics Results, 1078–1086. https://doi.org/10.1016/s1574-0722(07)00114-x	The study aims to examine the reliability of econometric estimators, particularly Ordinary Least Squares (OLS) and Two-Stage Least Squares (2SLS), in different market settings. The research investigates whether the choice of estimator should depend on the market institution generating the data and whether market-based experiments provide better insights into estimator performance.	Empirical study based on market experiments with controlled conditions.	The robustness of OLS and 2SLS estimators in different market institutions.	Experimental Market Design: The study employed laboratory market experiments to generate controlled data. Simulated Economic Conditions: Market demand and supply equations were designed to include demand and supply shift variables that are independently distributed to ensure competitive equilibrium. Estimation Methods: The study applies four econometric estimators: • Ordinary Least Squares (OLS) • Minimum Absolute Deviation (MAD) • Two-Stage Least Squares (2SLS) • Double Two-Stage Minimum Absolute Deviation (D2SMAD) Performance Evaluation: The estimators were assessed using Mean Absolute Percent Errors (MAPEs) in estimating demand and supply parameters across different market structures (competitive equilibrium, double auction, posted offer).	• OLS and MAD perform well with competitive equilibrium data. These estimators recover the true demand and supply parameters accurately when the market operates under competitive equilibrium conditions. • 2SLS and D2SMAD outperform OLS and MAD in double auction settings. Market data from double auctions introduce endogenous price formation, making single-equation methods less reliable. 2SLS and D2SMAD estimators adapt better to the simultaneity problem inherent in these markets. • OLS and MAD perform poorly with posted offer market data. The posted offer market introduces distortions because sellers post prices without knowing market demand. These distortions result in large MAPEs when using OLS and MAD estimators. • Market structure matters in estimator selection. No single estimator performs best in all market conditions. The suitability of an econometric estimator depends on the institutional characteristics of the market generating the data.	The study relies on controlled market experiments, which may not fully capture the complexities of real-world economic transactions.

7.	Dempster, A. P., Schatzoff, M., & Wermuth, N. (1977). A Simulation Study of Alternatives to Ordinary Least Squares. Journal of the American Statistical Association, 72(357), 77–77. https://doi.org/10.2307/2286909	The study aims to compare the performance of a collection of alternative regression techniques against Ordinary Least Squares (OLS) in multiple linear regression analysis. It seeks to evaluate whether alternative estimation methods can provide more robust and accurate coefficient estimation in the presence of collinearity, noncentrality, and multicollinearity among independent variables.	Simulation-based study Numerical experiment	Comparison of OLS with alternative methods	Simulation Design: The study uses factorial experimental design across multiple regression settings. It systematically varies conditions such as collinearity, eigenvalue structure, and degree of noncentrality. Multiple regression methods (OLS and 56 alternatives) are tested on 160 artificial datasets drawn from 160 normal linear models. Comparison of Estimators: Alternatives to OLS include ridge regression (various forms), Bayesian shrinkage methods, Stein-type estimators, and variable selection techniques. Performance metrics include squared error of regression estimates and prediction accuracy. Evaluation Metrics: Two primary error criteria: Sum of squared errors of estimates (SEB) Sum of squared prediction errors (SPE) F-statistics and significance testing are used to determine the influence of design factors such as collinearity and noncentrality.	OLS is inferior in almost all cases, particularly when collinearity and noncentrality are present. Ridge regression (RIDGM) and Stein-type estimators (STEINM) perform significantly better than OLS by reducing squared estimation errors. Bayesian shrinkage and variable selection approaches (FREGF, 1CPRI) improve performance, but their effectiveness depends on data structure and the degree of truncation. Noncentrality is a significant factor affecting all estimation methods, except OLS. FREGF provides the best performance in Experiment 1, while RIDGM is superior in Experiment 2. Variable selection-based methods (OFSLS, FREGF) perform well in some cases but show instability in others. Collinearity and multicollinearity negatively impact OLS significantly but are better handled by ridge regression and Stein-type estimators. Beta structure (true regression coefficients) significantly affects methods that involve variable selection (FREGF and OFSLS), making them highly sensitive to model specification.	The study focuses on a controlled set of artificial data and does not capture all potential real-world variations. Furthermore, while simulations provide insights, the results may not generalize fully to real-world econometric models with more complex dependencies.

8.	Flom, P. L. (2015). Alternative Methods of Regression when OLS is Not Right. SAS Global Forum.	The study aims to evaluate alternative regression methods for continuous dependent variables when Ordinary Least Squares (OLS) assumptions are violated. It explores alternative approaches such as Quantile Regression, Adaptive Regression Splines (MARS), and Transformations using PROC TRANSREG to address nonlinearity, multimodality, and heteroskedasticity.	Methodological Review and Applied Simulation Study	OLS and its limitations Alternative Regression Methods	Theoretical Justifications: The paper reviews key literature on alternative regression techniques. SAS-based Implementation: Quantile Regression (PROC QUANTREG): Demonstrated with birth weight data, showing the effect of maternal factors on different quantiles. MARS (PROC ADAPTIVEREG): Applied to auto mileage data to model nonlinear effects of weight, acceleration, and displacement. Transformations (PROC TRANSREG): Used to transform variables optimally before regression.	OLS is suboptimal when assumptions are violated: Quantile Regression provides a more robust alternative when the dependent variable is highly skewed or multimodal. MARS models outperform OLS in capturing nonlinear relationships and high-dimensional data interactions. Transformations (PROC TRANSREG) improve model fit by adjusting variable distributions before regression. Alternative methods offer more flexibility: OLS focuses on mean predictions, while alternatives allow insights across the distribution of the dependent variable. MARS and Transformations reduce residual errors, leading to better model performance.	Computational Complexity: Quantile regression, MARS, and TRANSREG require more computation time than OLS. Interpretability: MARS models, while effective, are harder to interpret than simple linear models. Generalizability: The study is limited to SAS-based implementations, meaning results may vary across other software.
9.	Greene, W. H. (1981). On the Asymptotic Bias of the Ordinary Least Squares Estimator of the Tobit Model. Econometrica, 49(2), 505. https://doi.org/10.2307/1913323	The study examines the bias of Ordinary Least Squares (OLS) estimates in limited dependent variable models, particularly in the Tobit and truncated regression models. It provides an analytical characterization of the bias and explores corrections using moment-based adjustments.	Theoretical and analytical study Empirical validation	Bias in OLS	Theoretical analysis: The study derives asymptotic properties of OLS estimators when applied to censored/truncated data. The author used moment-based corrections to adjust OLS slope coefficients. Analytical derivation of bias: The study examined how selection bias affects coefficient estimation.	OLS produces biased and inconsistent estimates in the presence of truncation: The slope coefficient estimates in OLS are biased downward due to the exclusion of nonlimit observations. The intercept term is overestimated because OLS fails to account for the truncated distribution. Monte Carlo evidence suggests that OLS bias remains stable across various data distributions.	The study's derivations depend on normality assumptions, limiting its generalizability to cases with non-Gaussian error distributions. Furthermore, although MLE-.

					Uses truncated normal moments to express how expected values deviate from classical regression assumptions. Empirical application: The author applied findings to a female labor supply dataset, comparing: OLS estimates Maximum Likelihood Tobit estimates Bias-corrected OLS estimates The empirical example highlights the extent of downward bias in OLS slopes when applied to censored data.	Even with bias corrections, OLS does not fully account for the data structure, making Maximum Likelihood Estimation (MLE) a superior choice.	based Tobit estimation is preferred, it is computationally more intensive than OLS, making it less accessible in some applied settings
10.	Helmreich, J. E., & Krog, K. P. (2017). Ordinary Least Squares and Quantile Regression: An Inquiry-Based Learning Approach to a Comparison of Regression Methods. PRIMUS, 28(3), 206–222. https://doi.org/10.1080/10511970.2017.1296911	The study explored and compared Ordinary Least Squares (OLS), Least Absolute Deviation (LAD), and Quantile Regression (QR) through an inquiry-based learning approach. It seeks to provide students with a deeper understanding of these regression methods, emphasizing their mathematical foundations, differences, and applications in real-world data analysis.	Pedagogical study	Comparative analysis of OLS, LAD, and QR regression methods	Practical Implementation: Students conducted experiments comparing OLS, LAD, and QR regressions. Computational exercises using R, Maple, and TI-84 calculators. Application-based activities to compare model robustness and sensitivity to outliers. Minimization of squared, absolute, and weighted deviations to explore different regression approaches.	OLS vs. LAD vs. QR OLS regression is useful for estimating the mean but can be sensitive to outliers and skewed data. LAD regression (minimizing absolute deviations) is more robust to outliers than OLS. QR provides greater flexibility by modeling conditional quantiles, offering insights into income inequality, extreme values, and distribution characteristics.	The study primarily emphasized mathematical and computational exploration, with limited real-world econometric applications.

11.	Horrace, W. C., & Oaxaca, R. L. (2006). Results on the Bias and Inconsistency of Ordinary Least Squares for the Linear Probability Model. Economics Letters, 90(3), 321–327. https://doi.org/10.1016/j.econlet.2005.08.024	The study aims to systematically establish the bias and inconsistency of Ordinary Least Squares (OLS) in the Linear Probability Model (LPM). It seeks to identify the conditions necessary for OLS to produce unbiased and consistent estimates and explores the potential of a "trimming estimator" as a corrective approach to mitigate OLS bias.	Theoretical and empirical econometric analysis	The bias and limitations of OLS in estimating the Linear Probability Model (LPM)	Theoretical derivation of bias and inconsistency in OLS applied to the LPM. Presentation of mathematical proofs showing the finite-sample and asymptotic biases of OLS when applied to binary outcome models. Introduction of a "trimming estimator" as a potential correction mechanism. Discussion of alternative estimation techniques such as logit and probit models.	OLS is generally biased and inconsistent when applied to the Linear Probability Model unless specific conditions hold. Heteroskedasticity and unbounded probability estimates (i.e., values outside [0,1] make OLS problematic for binary dependent variable models. Theoretical derivations confirm that the conditional expectation of OLS errors is not zero, violating a key assumption of OLS and leading to biased estimates of regression coefficients. Under certain conditions (when $\gamma = 1$), OLS can be unbiased and consistent, but these conditions are unlikely to hold in practice. A "trimming estimator" is proposed as a method to reduce OLS bias in LPM estimation by discarding extreme probability estimates. Comparison with logit and probit models shows that OLS does not provide reliable marginal effect estimates in cases where binary outcomes are modeled.	The study is theoretical and does not provide empirical and real-world validation of the proposed trimming estimator. Furthermore, the analysis is limited to LPM and does not explore more complex binary choice models with instrumental variable approaches.

12.	Inder, B. A. (1987). Bias in the Ordinary Least Squares Estimator in the Dynamic Linear Regression Model with Autocorrelated Disturbances. Communications in Statistics - Simulation and Computation, 16(3), 791–815. https://doi.org/10.1080/03610918708812619	The study investigates the bias in the Ordinary Least Squares (OLS) estimator in dynamic linear regression models where a lagged dependent variable is included as a regressor. It examines the effects of both independent and autocorrelated disturbances on the properties of the OLS estimator. The study also evaluates the asymptotic bias analytically and conducts a Monte Carlo (MC) study to assess finite sample bias. The findings highlight the necessity of alternative estimators and powerful tests for autocorrelation in dynamic models.	Empirical and analytical study involving theoretical analysis and Monte Carlo simulations.	The bias and limitations of OLS for dynamic linear regression models.	Analytical Approach: The study begins with a theoretical analysis of the asymptotic bias in the OLS estimator. It derives expressions for the bias when disturbances are independent and when they follow a first-order autoregressive (AR(1)) process. The analytical approach establishes that the bias increases with higher autocorrelation and error variance. Monte Carlo Simulation: The study conducts a series of Monte Carlo (MC) experiments to assess the finite sample performance of OLS estimators under different scenarios. Four experiments are designed using different exogenous variable matrices (including data from real-world economic time series) to observe the impact of sample size, error variance, and autocorrelation on OLS bias. Different parameter values are tested to evaluate the extent of OLS bias in dynamic regression models.	OLS is consistent but highly biased in finite samples: While OLS estimators retain consistency, their finite sample bias can be substantial, especially when error variance is high or sample sizes are small. This bias can lead to misleading inferences when applying hypothesis tests. Need for alternative estimators: The findings suggest that an alternative estimator with better finite sample properties is needed for dynamic regression models. Additionally, there is a strong need for hypothesis tests that accurately detect autocorrelation before applying OLS.	While the study highlights the need for alternative estimators, it does not propose or test specific alternatives to OLS.

13.	Karafiath, I. (2007). Is There a Viable Alternative to Ordinary Least Squares Regression When Security Abnormal Returns Are the Dependent Variable? Review of Quantitative Finance and Accounting, 32(1), 17–31. https://doi.org/10.1007/s11156-007-0079-y	The study investigates whether alternative regression methods can provide more reliable estimates than Ordinary Least Squares (OLS) when dealing with security abnormal returns as the dependent variable. It evaluates the performance of various regression techniques, particularly in the presence of event clustering, which induces heteroskedasticity and correlation across observations.	Quantitative empirical study using simulation-based analysis.	Robustness of OLS and alternative regression methods	Data Source: Daily stock returns from NYSE and AMEX obtained from the Center for Research in Security Prices (CRSP) as of December 31, 2004. Sampling Method: Random sampling of securities across different portfolio sizes (25, 50, and 75 securities). Simulation Setup: A total of 3,000 runs were conducted, assigning common event dates to each portfolio. Abnormal returns were randomly generated and added to the stock return data. Correlations were maintained within industries to simulate intra-industry clustering. Hypothesis Testing: Evaluated regression test statistics using different estimation methods, including: OLS (Ordinary Least Squares) WLS (Weighted Least Squares) GLS (Generalized Least Squares) Heteroskedasticity-consistent estimators (MW-HC, HC-WLS) Sefcik-Thompson Portfolio Approach (P-OLS, P-WLS, P-GLS) Bootstrap procedures were implemented to assess robustness.	OLS was found to be well specified but exhibited limited power in rejecting false null hypotheses. Weighted Least Squares (WLS) consistently outperformed OLS in terms of power but introduced a slight bias toward incorrectly rejecting the null hypothesis. Generalized Least Squares (GLS) performed poorly in hypothesis testing, frequently mis-specifying the test size. The Sefcik-Thompson portfolio-based methods (P-OLS, P-WLS, and P-GLS) showed varying degrees of over- and under-rejection depending on the event window length. Heteroskedasticity-consistent estimators (MW-HC, HC-WLS) provided mixed results, with MW-HC behaving similarly to WLS but with the disadvantage of incorrect test size in certain cases. The GLS bootstrap test was found to have a systematic tendency to over-reject the null hypothesis.	The study relied on simulated stock return data, which may not fully capture the complexities of real-world financial markets.

14.	Kline, T. J. B., & Klammer, J. D. (2001). Path model analyzed with ordinary least squares multiple regression versus LISREL. The Journal of Psychology, 135(2), 213–225. https://doi.org/10.1080/00223980109603692	The study aims to compare the effectiveness and theoretical strength of Ordinary Least Squares (OLS) regression and LISREL, a structural equation modeling (SEM) technique, in analyzing a specified path model. The research highlights the limitations of OLS in handling interdependent systems and demonstrates the advantages of using LISREL for modeling complex relationships.	Comparative methodological study	Path analysis; alternatives to OLS	Data Source: Collected data from 264 participants within the Canadian Forces. Variables Measured: Voice, perceived organizational support, being heard, and procedural justice. Techniques Used: OLS Regression: Used for estimating the relationships among variables in a recursive model. LISREL (Structural Equation Modeling - SEM): Used to evaluate interdependent relationships with latent constructs and measurement errors. Modeling Strategy: OLS was used to estimate path coefficients. LISREL was applied to estimate latent variable relationships and correct for measurement errors. Fit indices were compared to evaluate model adequacy.	OLS vs. LISREL: OLS assumes variables are measured without error and does not handle interdependencies among variables. LISREL provides a more flexible and realistic approach by allowing simultaneous estimation of all relationships in a model. Model Fit Comparison: The OLS regression model was found to be overidentified, with poor fit indices (chi-square value: 1847.02, statistically significant). LISREL provided better fit indicators and allowed for modification indices to improve model accuracy. Interaction and Mediation Effects: The LISREL approach confirmed indirect relationships between "voice" and "procedural justice," which OLS could not accurately capture. LISREL identified significant paths that were overlooked in the OLS analysis. Measurement Errors: LISREL accounts for measurement errors using latent variables, making it a more robust method for path analysis compared to OLS, which treats observed variables as error-free. Statistical and Theoretical Superiority of LISREL: LISREL's ability to model interdependencies makes it superior in cases where variables influence one another, unlike OLS, which assumes independent observations.	The study focuses only on one dataset and a specific social science application, limiting its generalizability to other domains.

15.	Mahaboob, B., Venkateswarlu, B., Narayana, C., Ravi sankar, J., & Balasiddamuni, P. (2018). A Treatise on Ordinary Least Squares Estimation of Parameters of Linear Model. International Journal of Engineering & Technology, 7(4.10), 518. https://doi.org/10.14419/ijet.v7i4.10.21216	The study aims to examine the estimation of parameters in a linear regression model using the Ordinary Least Squares (OLS) method, establish the Gauss-Markov theorem, and validate that OLS is the Best Linear Unbiased Estimator (BLUE) for linear regression. The study also extends the discussion to generalized linear models, ANOVA, and other estimation techniques.	Theoretical econometric analysis.	Theoretical foundation and statistical properties of OLS estimation.	Mathematical derivations and proofs to establish the properties of OLS estimators. Presentation of the Gauss-Markov theorem to show why OLS is BLUE. Development of the generalized Gauss-Markov theorem to handle cases where the assumption of homoskedasticity is relaxed. Formulation of the mean vector and covariance matrix of OLS estimators. Analysis of assumption violations (e.g., heteroskedasticity, autocorrelation, multicollinearity).	OLS provides unbiased and efficient estimates under standard assumptions. The Gauss-Markov theorem confirms that OLS is BLUE when disturbances have constant variance (homoskedasticity).	The study does not provide empirical validation or Monte Carlo simulations, relying entirely on mathematical proofs. The study assumes linearity and classical regression assumptions, limiting real-world applicability where these conditions do not hold.
16.	Merriman, M. (1877). On the History of the Method of Least Squares. The Analyst, 4(2), 33–33. https://doi.org/10.2307/2635472	The study aims to provide a historical overview of the development of the Least Squares method, tracing its various demonstrations, proofs, and contributions by different scholars. The objective is to highlight the origins, theoretical underpinnings, and alternative proofs of the method, including its mathematical justification.	Theoretical Analysis	Historical development of the Least Squares method.	Historical Literature Review: The study examines and compares original works and manuscripts of notable mathematicians. Comparative Proof Analysis: Various mathematical derivations and proofs are outlined and assessed based on their logical consistency and acceptance by mathematicians. Critical Evaluation: The study critiques certain assumptions and theoretical flaws in some demonstrations of the method.	The study situates OLS within its historical evolution, demonstrating its foundational role in statistical theory, while also recognizing its limitations and alternative derivations. Legendre (1805) is credited with first publishing the method in his work Nouvelles méthodes pour la détermination des orbites des comètes. He introduced the rule that the sum of squared errors should be minimized for best estimation. Gauss (1809) further developed the method, providing a theoretical justification through the assumption of normally distributed errors.	The assumption of normality in errors, which underpins the classical justification of Least Squares, is not universally applicable in econometric models.

						Laplace (1810) provided a proof based on the law of probability, which was regarded as a significant theoretical advancement. Hagen (1837) and Donkin (1844) proposed additional proofs relying on error algebra and statistical adjustments of observations. The study highlights various inconsistencies in some proofs, including questionable assumptions regarding error distributions and the arithmetic mean. Despite multiple alternative formulations, Gauss's proof (based on the normal distribution of errors) remains the most widely accepted.	
17.	Michaelides, P. G. (2024). Ordinary Least Squares. In 21 Equations that Shaped the World Economy (pp. 29–44). Springer Nature. https://doi.org/10.1007/978-3-031-76140-9_3	The study aims to provide a comprehensive exploration of Ordinary Least Squares (OLS) regression within the context of econometrics and economic research. It seeks to explain the mathematical foundations of OLS, its applications in various economic contexts, its role in decision-making, and the limitations and critiques associated with its use. The study further evaluates how OLS has shaped empirical economic analysis and policy assessment.	Methodological and applied	Historical development of OLS Critiques and limitations Role of OLS in econometric applications Alternatives to OLS	The study employs: Theoretical Discussion – A detailed exploration of the mathematical basis of OLS, including derivations of key equations and statistical properties. Applied Examples – Case studies demonstrating the use of OLS in different economic contexts, such as labor market analysis, consumer spending models, and financial market applications. Context of the Study – Focuses on how OLS functions in	Is OLS foundational? – The study reaffirms that OLS has been a foundational tool in econometrics, widely adopted due to its simplicity, interpretability, and robust applications in empirical research. Circumstances where OLS is effective – OLS is effective in analyzing relationships between economic variables, policy evaluation, and forecasting when its core assumptions (linearity, exogeneity, homoscedasticity, and lack of multicollinearity) hold.	While the study provides theoretical insights and mathematical formulations, it does not conduct an empirical assessment to compare OLS performance with alternative estimation techniques in real-world datasets.

					real-world economic settings, with an emphasis on its role in empirical economic research, decision-making, and statistical inference.	Circumstances where OLS is ineffective – The study acknowledges that OLS may be inappropriate when these assumptions are violated, particularly in cases of non-linearity, heteroscedasticity, omitted variable bias, or endogeneity.	This limits the study's ability to demonstrate the practical effectiveness or shortcomings of OLS in applied settings.
18.	Mukhopadhyay, P., & Schwabe, R. (1998). On the performance of the ordinary least squares method under an error component model. Metrika, 47(1), 215–226. https://doi.org/10.1007/bf02742874	The study evaluates the performance of the Ordinary Least Squares (OLS) estimator in comparison to the Best Linear Unbiased Estimator (BLUE) within an error component model that incorporates random effects in both units and time.	Theoretical and methodological, focusing on the mathematical properties of OLS within an econometric framework	Variance components and efficiency of OLS Comparison of OLS and BLUE estimators.	Mathematical Derivations: The study employs algebraic manipulations, matrix calculus, and statistical theory to compare the performance of OLS and BLUE.	OLS Efficiency Loss: The OLS estimator generally performs worse than BLUE under an error component model due to ignoring correlation structures in the data. Upper Bounds on the Difference: The study establishes upper bounds on the deviation of OLS from BLUE, highlighting situations where OLS exhibits substantial inefficiency. Spectral Norm Results: The spectral norm of the dispersion matrix shows a clear divergence between OLS and BLUE, reinforcing the limitations of OLS under specific econometric conditions. Role of Variance Components: The extent of OLS inefficiency depends on the proportion of variance components attributed to unit-level effects and time-level effects.	The study relies entirely on theoretical derivations without empirical validation using real-world data.

19.	Nalewaik, J. J. (2008). Lack of Signal Error (lose) and Implications for OLS Regression: Measurement Error for Macro Data. Finance and Economics Discussion Series, 2008(15), 1–49. https://doi.org/10.17016/feds.2008.15	The study introduces a generalization of the classical measurement error model by incorporating Lack of Signal Error (LoSE), a type of measurement error that subtracts signal rather than just adding noise. It explores the implications of LoSE for Ordinary Least Squares (OLS) regression, particularly in the context of US macroeconomic quantity data (e.g., GDP growth). The goal is to demonstrate how LoSE can introduce biases opposite to those caused by classical measurement error, affecting inference and estimation.	Theoretical and empirical study	Bias of OLS	Generalization of the Classical Measurement Error Model: The study expands on the traditional model by introducing LoSE, which reduces variance rather than inflating it, as is common with Classical Measurement Error (CME). Mathematical Derivations and Statistical Proofs: The paper formally derives the effects of LoSE on bias, consistency, and inference in OLS regression. Empirical Tests Using US Macroeconomic Data: The study compares GDP and GDI growth estimates over time, showing how revisions reduce LoSE. Regression analysis is conducted using GDP growth estimates with varying levels of LoSE as dependent variables and asset prices (e.g., stock market data) as independent variables. Differences in coefficient estimates across various revisions of GDP growth data are analyzed to detect biases introduced by LoSE.	This study provides a strong theoretical and empirical evidence that OLS is not always reliable in the presence of measurement errors like LoSE. This challenges OLS's position as the cornerstone of econometric theory, at least in macroeconomic applications where GDP and similar data are widely used. LoSE Reverses Conventional Understanding of Measurement Error in OLS: Classical Measurement Error (CME) in explanatory variables causes attenuation bias (bias toward zero). LoSE in the dependent variable can also introduce attenuation bias, contradicting the classical assumption that measurement error in Y is harmless.	The findings are highly relevant for macroeconomic estimation but may not generalize to microeconomic or other econometric applications.

20.	Peel, M. J., Goode, M. M. H., & Moutinho, L. A. (1998). Estimating Consumer Satisfaction: OLS Versus Ordered Probability Models. International Journal of Commerce and Management, 8(2), 75–93. https://doi.org/10.1108/eb047369	The study aims to evaluate the effectiveness of Ordinary Least Squares (OLS) regression in estimating consumer satisfaction and compare its performance with ordered probability models (ordered logit and probit models). It investigates whether OLS is appropriate when dealing with ordinal dependent variables.	Empirical study with statistical modeling	The performance of OLS and Alternatives	The study uses survey data collected from 445 consumers in Cardiff (UK) regarding car satisfaction. It applies OLS regression, ordered logit, and ordered probit models to analyze the impact of various independent variables (e.g., expectations, price, brand loyalty) on consumer satisfaction. The models' predictive accuracy and explanatory power (R^2, pseudo-R^2) are compared.	OLS produces misleading results when applied to ordinal categorical data, as it assumes an interval scale for the dependent variable. Ordered probability models (logit and probit) are superior for ordinal dependent variables, offering more reliable coefficient estimations and avoiding biases associated with OLS. OLS underestimated the impact of some key variables due to its inappropriate assumption of linearity in ordinal data. The classification accuracy of OLS was significantly lower (40.7%) compared to ordered logit (56.2%) and ordered probit (55.5%). Sensitivity analysis confirmed that ordered probability models provided better predictions and more robust coefficient estimates.	The model includes a limited set of explanatory variables
21.	Sapra, S.K. (1998). Bias and Inefficiency of an Ordinary Least Squares Estimator for Logit Regressions with Continuous Dependent Variables Measured with Error. Applied Economics Letters, 5(12), 745–746. https://doi.org/10.1080/135048598353925	The study aims to examine whether the OLS estimator is unbiased or inefficient in a logit model with a continuous and bounded dependent variable measured with error. It critiques Manning's (1996) claim that OLS is unbiased but inefficient and instead argues that OLS is biased in general.	Theoretical and methodological critique	The bias of OLS	The study applies Taylor series expansions to analyze claim about the unbiased nature of the OLS estimator. - It mathematically examines heteroscedasticity properties of error terms and their impact on the OLS estimator. - It critiques assumptions made in prior studies about measurement error distribution and its implications for OLS efficiency.	The study finds that OLS is biased rather than just inefficient when applied to logit models with measurement error in the dependent variable. The presence of nonzero expectations for second- and third-order Taylor series terms leads to bias in the OLS estimator.	The study is largely theoretical and does not provide empirical validation through simulations or real-world data. It focuses specifically on the logit model with a bounded dependent variable, which may limit generalizability to other econometric models.

22.	Sheynin, O. (2014). C.F. Gauss and the Method of Least Squares. Śląski Przegląd Statystyczny, 12(18). https://doi.org/10.15611/sps.2014.12.01	The study aims to explore the historical development of the Method of Least Squares (MLSq), with a focus on the contributions of Carl Friedrich Gauss. It traces the evolution of the method, highlights key contributors such as Legendre, Adrain, and Helmert, and critically examines the mathematical foundations and controversies surrounding its development.	Theoretical Review	Historical origins	Historical and Conceptual Analysis: The study reviews primary sources, including Gauss's original works, correspondence, and subsequent refinements by other mathematicians.	The study confirms that OLS estimators are efficient under normality assumptions but acknowledges that non-normal error distributions can lead to inefficiency and bias. Gauss's derivation using Maximum Likelihood Estimation (MLE) was later challenged but remains foundational in regression theory. The Gauss vs. Legendre priority dispute is discussed, with Gauss asserting that he had used Least Squares since 1795 but only published it later. The study critiques Gauss's assumption that observational errors follow a Normal Distribution, a premise that later statisticians such as Markov and Fisher revised.	The study primarily focuses on 18th and 19th-century mathematical developments, limiting its direct application to modern econometric advancements.
23.	Stigler, S. M. (1981). Gauss and the Invention of Least Squares. The Annals of Statistics, 9(3), 465–474. https://doi.org/10.1214/aos/1176345451	The study examines the historical priority dispute between Carl Friedrich Gauss and Adrien-Marie Legendre regarding the discovery of the Least Squares Method. It evaluates documentary and statistical evidence to determine whether Gauss had prior knowledge of the method before Legendre's 1805 publication.	Historical and analytical study.	The origins of the Least Squares Method	Historical Document Analysis: The study reviews primary and secondary sources, including Gauss's unpublished writings, letters, and references in contemporary scientific literature. Mathematical Analysis: The study evaluates Gauss's calculations and theoretical justifications for least squares, particularly in his work related to geodesy and meridian measurements.	While Gauss claimed to have used the method since 1795, there is limited concrete evidence that he formally developed or applied it before Legendre's publication in 1805. Gauss's 1799 and 1806 writings contain references that could suggest knowledge of least squares, but they do not explicitly establish priority. Legendre provided the first formal and published description of the method, which gained widespread acceptance.	The study relies on historical documentation, which may be incomplete or subject to interpretational bias. Gauss's unpublished notes and letters introduce uncertainty regarding the actual timeline of his discoveries.

					Comparative Evaluation: Contrasts the claims of Gauss, Legendre, and other contemporaries (such as Robert Adrain) based on historical timelines and available records.	The statistical method itself was likely developed independently in different contexts, with Gauss later refining and extending it through probabilistic interpretations. The evidence supporting Gauss's claim is inconclusive due to the lack of clear pre-1805 documentation.	The mathematical reconstructions of Gauss's work depend on secondary sources and retrospective analysis, which may not fully capture his original methods.
24.	Vinod, H. D. (1978). A Survey of Ridge Regression and Related Techniques for Improvements over Ordinary Least Squares. The Review of Economics and Statistics, 60(1), 121–131. https://doi.org/10.2307/1924340	The study aims to review ridge regression and related statistical techniques as alternatives to Ordinary Least Squares (OLS) regression, particularly in addressing multicollinearity issues. It seeks to explore theoretical justifications, practical implementations, and limitations of these alternatives.	Literature review	Alternatives to OLS	Theoretical Analysis: The study examines mathematical formulations of ridge regression, mean squared error (MSE) analysis, and bias-variance trade-offs. Comparative Evaluation: It reviews Monte Carlo simulations and empirical results from prior studies that compare the performance of ridge regression and OLS. Exploration of Variants: It discusses variations like Generalized Ridge Regression (GRR), Principal Components Regression (PCR), Bayesian Ridge Regression, and Stein-rule estimators.	Ridge Regression Reduces Variability: Ridge regression can reduce the variance of OLS estimators, making it more stable in cases of multicollinearity. Trade-off Between Bias and Variance: While RR introduces bias, it often leads to lower MSE compared to OLS in the presence of multicollinearity. Ridge Trace Helps Identify Stability: The study highlights the importance of the ridge trace method to select the appropriate ridge parameter. Bayesian and Stein-Rule Approaches Extend RR: These methodologies provide additional shrinkage techniques that improve estimator stability. OLS Can Be Problematic in Finite Samples: The study shows that OLS estimates can be highly unstable when sample sizes are small and predictors are correlated.	The effectiveness of RR varies depending on the dataset, making general recommendations difficult.

25.	Watson, P. K. (1983). Kalman Filtering as an Alternative to Ordinary Least Squares: Some Theoretical Considerations and Empirical Results. Empirical Economics, 8(2), 71–85. https://doi.org/10.1007/bf01973191	The study aims to highlight the superiority of the Kalman filter over Ordinary Least Squares (OLS) in estimating unknown coefficients of the classical linear regression model. The author evaluates both methods concerning their optimality properties and ability to handle multicollinearity, a common problem in econometric modeling.	Theoretical and Empirical Study	Alternative to OLS	Theoretical Analysis: Discusses the classical linear regression model (CLRM) and the optimality properties of OLS. Defines conditions under which OLS is optimal and when it fails due to violations of key assumptions. Introduces the Kalman filter as an extension of OLS, highlighting its advantages in handling multicollinearity and estimation uncertainty. Empirical Analysis: Applies OLS and Kalman filtering to two economic models: (i) Klein's Investment Model – using time-series data on investment, profits, and capital stock. (ii) Theil's Textile Model – estimating demand elasticity for textiles in the Netherlands. Uses Recursive Least Squares and Pure Kalman Filtering with different parameter values. Tests optimality and reliability of both methods using Von Neumann Ratio (VNR) and bias tests.	OLS Assumptions Are Often Violated in Practice: OLS is theoretically optimal under certain assumptions, but these assumptions are rarely met in real-world economic data (e.g., time-series models). Issues such as heteroscedasticity, autocorrelation, and multicollinearity undermine OLS estimates. Kalman Filtering Is a More Flexible and Reliable Alternative to OLS: Handles multicollinearity better than OLS by iteratively updating estimates as new observations arrive. Unlike OLS, does not require full data availability at once – useful for real-time estimation in economic modeling. Produces more stable estimates than OLS in the presence of severe collinearity. Comparison of Klein's and Theil's Models: Klein's Model: OLS was found to be suboptimal, while the Kalman filter provided optimal estimates for certain parameter choices. Theil's Model: OLS was optimal but severely affected by multicollinearity. Kalman filtering, for specific values, produced more reliable but biased estimates, similar to ridge regression.	In some cases (e.g., Klein's model), Kalman filtering provided optimal estimates, but in others (e.g., Theil's model), it required careful tuning to outperform OLS. Compared to OLS, Kalman filtering is computationally intensive, which may be a drawback for large datasets.