REDEFINING MACROECONOMIC FORECASTING: VALIDATION OF A NEW FRAMEWORK

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Economic crises expose the failure of macroeconomic forecasting to provide reliable, actionable insight. Despite adopting scientific language, economic models remain grounded in unvalidated theory and political ideology. This white paper introduces Economy Dynamics, a new forecasting framework that redefines economic modelling through the proven Validation and Verification (V&V) methodology used in engineering and the applied sciences.

1 THE CURRENT ECONOMICS FRAMEWORK

Exploring the foundations of economic thought explains why economics has evolved without a unified, testable framework, and offers insight into how such a framework might now be developed. Economics has embraced diverse influences in the search for understanding, drawing from philosophy, mathematics, science, psychology, and politics. This interdisciplinary richness has shaped both its models and its assumptions, but it has also produced a conceptual patchwork of distinct and often incompatible ideas. The result is our inability to predict the effects of economic policies [1].

Modern economics rests on conflicting philosophical foundations. Descartes' rationalism inspired abstraction and deductive modelling [2], meanwhile Hume emphasised empiricism and the flaws of reasoning [3]. Following a rationalist approach, Mandeville postulated that the greed of individuals could lead to collective benefit [4], which Smith developed into a theory of market-based economics [5]. Now in the age of big data and digitally auditable financial transactions, the role of empiricism is gaining prominence, but with resistance as it cannot align to the *a priori* rationalist theories.

The philosophical divide is most prominent in the mathematical forecasting models used to support policy decision-making. The *structural* models (such as the Dynamic Stochastic General Equilibrium method) are the stalwarts of the rationalist theories, simulating rational agent responses to economic stimulus [6]. This contrasts with the *non-structural* models, which are statistical-based, empirical tools such as Vector Autoregressive models used for forecasting indicator variables [7,8]. In the middle are the *hybrid* models, that include the Stock-Flow Consistent models, seeking to demonstrate rationalist theories through partial implementation of empirical mechanisms [9].

Economics has sought credibility by borrowing metaphors from science, the bastion of empiricism, to shape its theories. Walras adapted Newtonian mechanics into equilibrium models [10]; Phillips represented macroeconomic flows as hydraulic systems [11]; and Nelson and Winter introduced evolutionary theory, replacing equilibrium with adaptation [12]. Though inspired, they are analogies of another discipline and not theories of economics. As analogy can only explain an unfamiliar phenomenon in the context of a familiar one, ultimately it confuses rather than informs.

Despite its scientific aspirations, economics lacks a testable framework. The consequences are catastrophic: economic crashes are linked to an increase in suicide rates in the tens of thousands [13]. In comparison, industries like aerospace reduce such catastrophic risks [14] through rigorous validation and verification (V&V) of models [15], guided by centralised requirements that evolve through lessons learned, captured in certification specifications [16]. In contrast, even the purpose of using economic policy making metrics are not clear, such as *growth,* which functions as a proxy for ambiguous and undefined benefits to the economy. Under the current approach to knowledge, this prevents constructive evaluation of the effectiveness of policies.

Economic theory shapes the policies and institutions, such as central markets, that impact billions of lives. Yet without a unified, testable framework, these policies are often guided by political ideology. As a result, unresolved tensions persist between free market advocates [17,18], proponents of state control [19,20], targeted interventionists [21,22], and environmental economists [23,24]. Economics must embrace the same rigorous validation and verification process of engineering. The project defined in this white paper will do that by validating a new forecasting framework, *Economy Dynamics*.

2 STATE-OF-THE-ART MACROECONOMICS

The state of macroeconomic forecasting is expressed by the recollections of Haldane [25] a past Chief Economist at the Bank of England (2014-2021). He recalls, that in the early years of inflation targeting, the head of forecasting entered his room clutching a piece of paper. On it were two lines; the analytical inflation forecast and a projection hand-drawn by the governor. Only the latter was published. Since then, he considers the process of economic forecasting to have remained essentially unchanged: largely performative, typically opaque, nine parts art to one part science.

In response to the rejection of their hard work, analysts introduced confidence bands to convey uncertainty (Figure 1). But these are not empirically derived. They do not reflect sensitivity to initial conditions, as in weather forecasting, nor represent statistical uncertainty in fitted parameters. Instead, they are subjectively assigned and offer no verifiable insight into forecast reliability beyond the forecasters' judgement. At best, they ensure the reader appreciates the level of uncertainty.

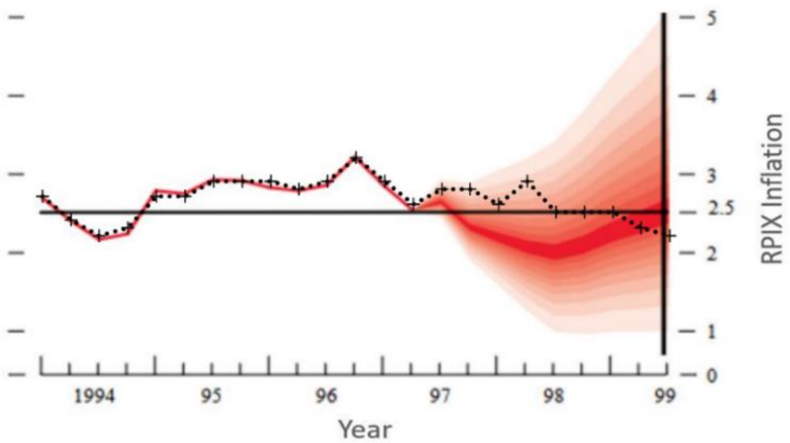


Figure 1. Inflation projection in 1997 [26]: red) original fan-plot; black) historical data from the ONS [27]

Comparing forecasts to historical data (Figure 1) reveals little about model failure. In applied sciences, models are rerun using historical inputs to assess predictive error—providing insight into model limitations, which guides further research to continuously advance knowledge [29,30]. Economics cannot implement this process. As Pagan [31] notes and Figure 2 illustrates, economics struggles to reconcile theoretical and empirical coherence. The structural and hybrid models implement untestable theories, by different approaches, and the non-structural statistical models extrapolate past correlations, all with the same results: errors in the prediction of recent historical data provides no useful information about the failure of the theory.

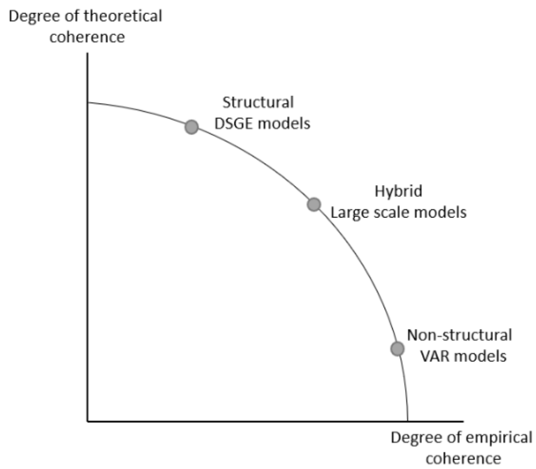


Figure 2. Trade-off between theoretical and empirical coherence in macroeconomic models [28]

3 THE VALIDATION AND VERIFICATION APPROACH

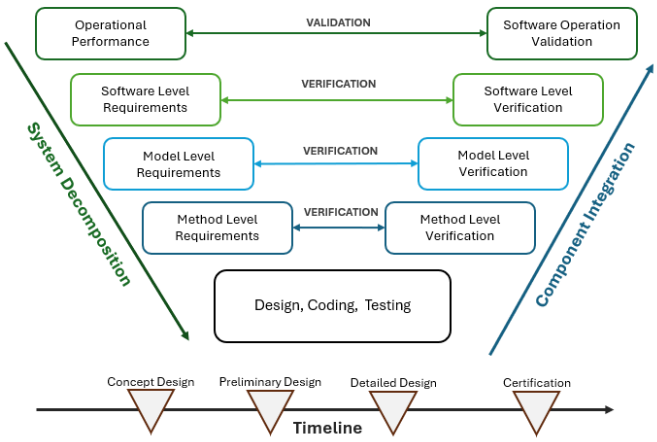
Economy Dynamics is a new framework for macroeconomic forecasting that applies the validation and verification methodology to modelling economic behaviour. The V&V process, breaks down complex systems into manageable components, rigorously tests them, and then reassembles them into reliable, testable frameworks [32-34]. The V&V process is an extension of scientific methodology.

Popper [35] proposed that the criterion of scientific method is falsifiability. Feynman [36] described this as a process for creating scientific laws: (i) guess a hypothesis, (ii) compute the consequences, (iii) compare these to experiment or observation, and (iv) if it disagrees, reject it. This approach produces knowledge of the constituent components (structures) and processes (laws) of the world around us. Scientific methodology is extended by the V&V process to produce knowledge of the behaviour of complex systems. Like engineering and the other applied sciences, economics claims to enable us to manage our environment.

The V&V methodology is applicable to economics, as proposed by Maybury, 2020 (Paper00) [37]. Economic behaviour follows causal rules; financial systems are traceable through audit trails. As business activities can be audited, macroeconomic processes can be understood through the data and processes of households and businesses [37-40]. By following the V&V process, we move beyond models built on abstract theories and/or extrapolated correlations.

Unlike judgement-based models that produce non-correctable errors and inconsistent results [41], the V&V methodology follows best-practice standards to achieve empirical consistency and reproducibility [42]. By modelling system mechanisms, not just forecasting output variables, the proposed framework can simulate not only GDP and inflation, but any suitably quantified characteristic of economic structures, including unemployment levels, regional inequalities, and environmental impact. It enables systematic testing of competing theories and supports policy evaluation grounded in verifiable cause-and-effect relationships.

The V-diagram graphically represents the V&V methodology, shown in Figure 3 for economics. The methodology operates at all levels of software development, from a set of equations (known as a method), checking that the lines of code represent the behaviour correctly and that the method is validated against empirical data; to the whole software, checking that the combined models (comprising of methods) represent the system correctly and is validated against empirical data. This is achieved by defining requirements for each level (software, model, method) at the decomposition stage, and verifying they are met at each integration stage (method, model, software), before validating the operational performance of the software. Figure 3 (Table) shows sample Economy Dynamics requirements following the V&V methodology, which is absent from current theories.



Example Requirements			
ID	Type	Level	Description
OP-003	Customer	Operation	Software shall produce testable forecast metrics for fiscal policy analysis: GDP, Tax Revenues, Employment.
SW-009	Functional	Software	Software shall simulate global, national, and regional level economic behaviour.
MDL-004	Functional	Model	Models shall encapsulate economic mechanisms: consumer decision making, financial pressure, and retailer decision-making.
MTH-003	Functional	Method	Retailer decision making (pricing hypothesis) shall include supply chain effects on the cost of production.

Figure 3. Software development process: V-Diagram and sample Economy Dynamics requirements.

4 COMPARING FORECASTING APPROACHES

In economics, the absence of systematic validation has led to a proliferation of incompatible model types – each claiming coherence, yet none proving superiority through testable forecasts. Policy making, therefore, uses a numerous methodologies. Recent reviews and discussions of the different approaches include: large-scale models [28,43-47]; hybrid models [9,48]; and statistical models [49,50]. Within all these models there are mathematical deficiencies that prevent validation, regardless of whether the models appear coherent to theory or data. The key issues, as discussed by Maybury [37], are twofold:

- These models neglect key mechanisms (and so system information), such as supply chain credit terms, price competition and the change in behaviour due to financial circumstances.
- They rely on extrapolated correlations – all models forecast household consumption using historical averages – which leads to unknowable errors that cannot be meaningfully corrected.

Economy Dynamics has some similarities to existing methods. Like Stock-Flow Consistent (hybrid) models it uses explicit mechanisms (e.g., price = cost + margin), but it is not biased upon unvalidated economic assertions. Like Agent-Based Models (ABMs) [51,52], household behaviour is modelled as a response function. However, ABMs simulate individual agents, which makes whole economy modelling computationally infeasible. *Economy Dynamics* applies Bernoulli's law of large numbers [53] to model group-level probabilities. This enables modelling at global scale without neglecting system variables.

You may ask – how can one avoid neglecting critical variables in such a large, complex system? The answer lies in the V&V methodology [29,32,33]. This process ensures that the appropriate models are correctly implemented to fulfil the system requirements [34].

5 EXTENDING RESEARCH BOUNDARIES

This project will implement a step-change in economic methodology by extending the systems-engineering paradigm of the V&V methodology into macroeconomic forecasting, enabling reproducible, component-based, and causally grounded modelling. Instead of mimicking scientific principles through analogy, economics will benefit by adopting the methodologies used in engineering to design and control complex systems.

It applies engineering rigour to develop a reproducible economic forecasting framework exploiting advances in data science. Using the V-diagram, the framework allows models to be validated both separately and collectively [54]. It supports collaborative research, enabling independent teams to develop, and validate distinct components of the system [37-40,55-61]. Forecasting can become repeatable, testable, and transparent, by implementing the following approach:

- Surrogate modelling of household and business decisions using economic groupings and financial pressure avoids the need to extrapolate correlations of historical data [38,57].
- Mechanistic modelling of income-expenditure financial dependencies implements the effects of fiscal and monetary policy on consumer and retailer economic behaviour [39].
- Retailer price modelling, based on observable processes links geographic and temporal effects on input costs, which offers insight into inflation dynamics [40].
- Automated testing pipelines provide continuous verification and validation and report the effects of new model development on past model prediction quality [60,61].

6 ABOUT THE PROJECT

6.1 METHODOLOGY

The proposed forecasting framework is defined in Maybury, 2020, Paper 00 [37]. The research involves defining requirements, building the models, and verifying each level of the system – methods, models, and software – against those requirements. Each will be empirically tested against validation metrics applied to ensure completeness and predictive reliability.

The models identified include:

- Household and business financial circumstance behavioural models [38,57]
- Governing equations capturing income and expenditure interdependencies [39,55]
- Price-setting mechanisms based on cost and competition [40]
- Consumer life cycles modelling of key economic event transitions [56]

- Land & wage pricing models based on observable behaviour [58,59]
- Validation and Verification automated retrospective testing of forecasts [60]
- Scalable computational architecture for large-scale simulation [61].

6.2 *Development Phases*

The five-year project will follow an iterative systems engineering lifecycle, progressively increasing maturity through three development stages (Figure 3), supported by continuous project management and dissemination. The work packages are as follows:

1. **Concept Design Phase** (Month 1 to 24): This phase defines the forecasting framework requirements, and designs, implements, and tests a concept prototype. It identifies framework weaknesses and explores solutions. The initial open-source concept release will enable independent testing and early feedback, with the aim of establishing a community of interested developers.

2. **Preliminary Design Phase** (Month 25 to 42): Refines the initial concept and formalises method, model and system-level specifications. The system architecture will be validated against performance targets and usability requirements. A software alpha release will be published for broader testing.

3. **Detailed Design Phase** (Month 43 to 56): Finalises the system architecture and refines all models based on validation results. Verification and sensitivity analysis ensure robustness. The phase concludes with a critical design review and beta release of the forecasting software.

4. **Project Management and Dissemination** (Month 1 to 60): Staffing and contractor engagement, stakeholder relations, software release cycles, and the commitment to open science.

6.3 *Project FEASIBILITY*

The principal investigator is uniquely equipped to lead this research through his combination of scientific insight, engineering rigour, research leadership and business experience. This research also exploits IP developed in previous projects co-funded by the host organisation, Axsym Limited [62], and Innovate UK [63], proving the concept of the software architecture and demonstrating surrogate model use for industrial applications. The development of a repeatable, testable framework has low technical risk by using well established engineering methodologies. The main challenge is achieving substantive validation results. However, the framework is designed to support ongoing improvement, enabling other researchers to extend and refine the models developed in this project. A further challenge is associated with the need to manipulate historical data inputs to align with the structure of the new framework, for which Agent-Based Models can be used.

6.4 *Commitment to Open Science*

The project will release all publications and datasets following the ERC open-access guidelines [64]. The software developed will be open source and the project will include dissemination tasks, such as workshops. This ensures that the methodologies, findings, and tools developed will be available for further scientific research.

7 CONCLUSION

This project represents a fundamental shift in economic research, one that moves economics from a social science into the realm of the empirical sciences. By adopting scientifically verifiable frameworks and applying Verification and Validation (V&V) methodologies, it addresses the core limitation in economic forecasting. The result is a new standard of reproducibility, empirical rigour, and methodological clarity. Economic models are treated not as monolithic tools but as distinct research programs, each open to scrutiny, refinement, and empirical testing. Peer review will shift from evaluating the adherence to theoretical assumptions toward evaluating transparent and testable methods. In doing so, this research will give policymakers access to scientific tools for evaluating economic and environmental policy, aligning economics with the standards of modern science and engineering.

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63. This research exploits IP developed in previous projects co-funded by Axsym Limited and Innovate UK (project no. 132456 & 710722) that proved the concept of an innovative computational framework for automating data intensive simulation processes and (project no. 70021) that evaluated the concept of using surrogate modelling methods for reducing costs in industrial processes.
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